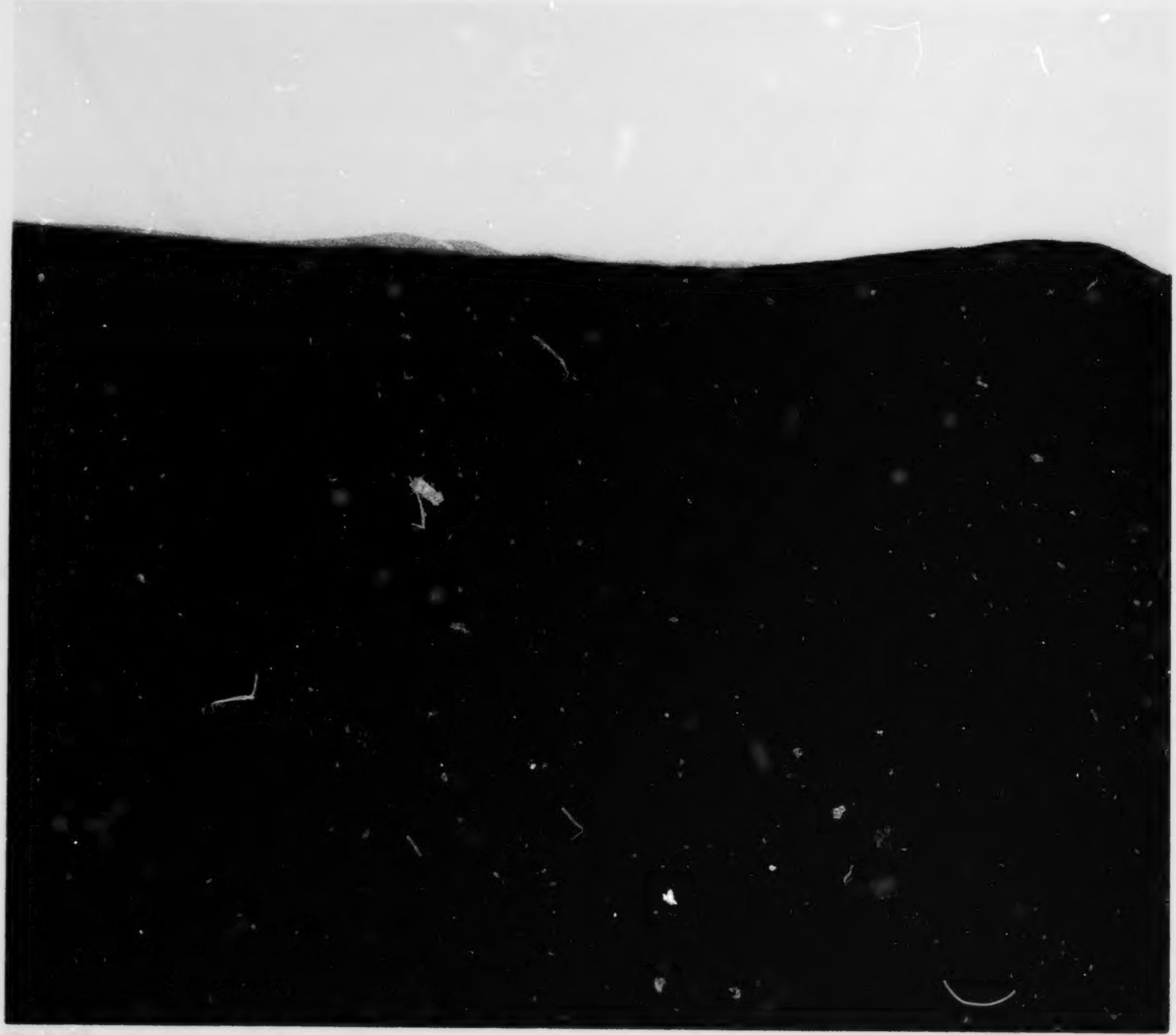
Canada's Timber Resources

Edited by
David G. Brand
Petawawa National Forestry Institute • Information Report PI-X-101



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CANADA'S TIMBER RESOURCES

Proceedings of a national conference
held 3-5 June 1990 at the Victoria
Conference Centre, Victoria, British Columbia

Edited by
David G. Brand

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Preface

These are the proceedings of "The national conference on Canada's timber resources" held June 3-6, 1990 at the Conference Centre in Victoria, British Columbia. The purpose defined for the conference was to "review and improve our knowledge of Canada's forests, their area and wood volume, accruals and depletions, and the prospect for sustained yield and sustainable development in the future up to the year 2050." The objective was not only to present current statistics, technical information, and overall perceptions of speakers but also to formulate recommendations that could be brought forward to the Canadian Council of Forest Ministers.

The conference was initiated by staff of the Science Directorate in Forestry Canada's headquarters, and was financially cosponsored by Forestry Canada and the British Columbia Ministry of Forests. The organizing committee of the conference included Dr. Fred Pollett of Forestry Canada and Frank Hegyi of the British Columbia Ministry of Forests as cochairmen, Dr. Terry Honer as Program Chairman, and Jack Smyth, Susan Barnabe, Dave Boulter, Bob Dobbs, Dave Brand, Gilles Frisque, and Jim Richardson as organizing committee members. The conference was chaired by Dean Gordon Baskerville of the University of New Brunswick. Conference services were organized by Penny Walker, with the able assistance of Tammy Renton. Thanks also go to session chairmen and rapporteurs, including Claude Godbout, John Cuthbert, Andre Duchesne, Peter Murphy, Jack Smyth, John Drew, John Osborne, Bob Lamont, Al Van Sickle, and Jim Cayford.

These proceedings reflect largely the formal papers presented at the conference. They do not include the speeches by Ministers and Deputy Ministers, the opening and closing comments of conference chairman Dean Gordon Baskerville, or the comments and questions from the floor. The papers have been systematically edited to impart a common style. Any errors, omissions, or changes in the sense of the papers are the responsibility of the editor.

David G. Brand

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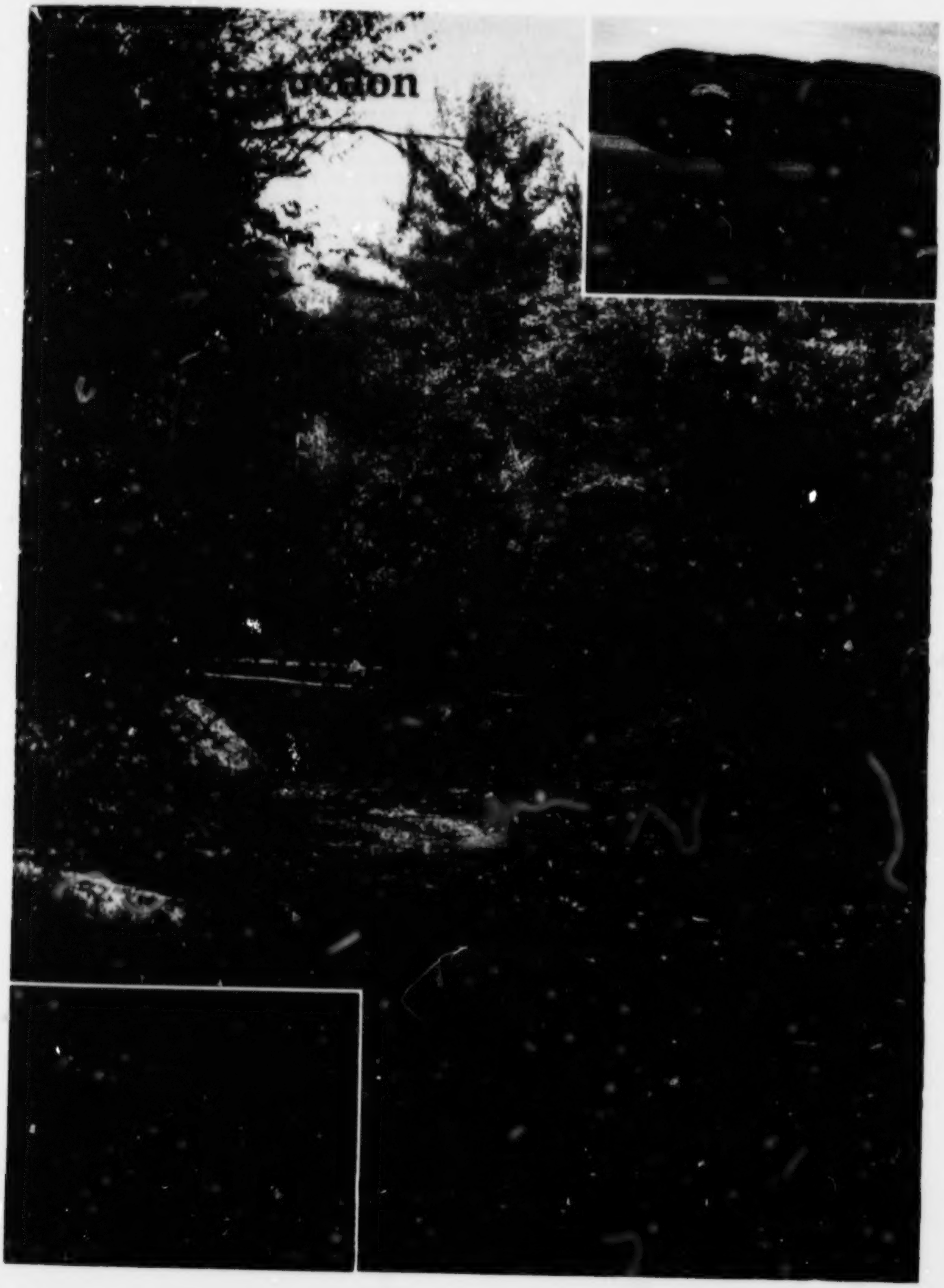

Introduction

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After decades spent bemoaning the lack of public interest in forest management and the lack of government commitment to investment in silviculture, Canadian foresters have been taken aback by the increasing public interest in their activities. It seems that every day a new issue emerges having direct impact on forest management, whether it is preservation of a valley; creation of a new park; opposition to a forest management practice, such as clear-cutting; or claims that harvest rates are unsustainable. Suddenly, foresters and politicians find themselves on the defensive, and sadly lacking in much of the information necessary to defend current practices or even lead a discussion of future alternatives. At the political level, it has been a source of frustration to forest ministers that good data are not available on the nature and extent of the Canadian forest, its rates of growth, and the rates of harvesting, wildfire, or pest damage. Statistics on the activities related to forest management, such as tree planting, fire suppression, or pesticide use, are often difficult to obtain, or several years out of date.

This lack of information on the Canadian forest and on our national performance in managing that forest was the impetus behind the development of the conference on which these proceedings are based. The following papers systematically present the best current information we have on the extent and nature of the Canadian forest; the rates of growth, harvesting, and damage by pests; and the forecast of future wood supplies over the next half century. The book is divided into five parts, presenting an overview of the situation, descriptions of the forest inventory, information on forest growth, information on harvesting and damaging agents, and predictions of the future wood supply in Canada. The papers include reviews of what we know, and specific case studies or technical articles on provincial or industrial policies. I hope all readers find something of interest in these papers, whether as an introduction or as a reference on current knowledge and practice in Canadian forest management.

The sessions at which the papers were presented generated a series of recommendations for consideration by the Canadian Council of Forest Ministers. Those recommendations were discussed in a final plenary session of the conference. The communiqué issued at the end of the conference made the following four recommendations:

1. Develop models for Canada's national forest inventory that would be capable of showing the impacts of increases and depletions in the forestland base.
2. Expand traditional timber inventories to include other resources, such as wildlife, soil, recreation, and cultural and heritage values.
3. Provide the financial resources necessary to acquire this dynamic inventory model, estimated to cost $2.00 per hectare. Given 243 million ha of productive forestland in Canada, this means a commitment of $486 million over 5 years, i.e., $97.2 million per year.
4. Involve special interest groups in the development of this dynamic model on Canada's forest resources.

The conference concentrated on timber resources, as opposed to forest resources. This focus on timber, although potentially appearing backward-looking, was specifically designed as the first phase of a two-phase process. This conference resulted in defining the timber resource, the need for enhancements in the current information base, and the outlook for future timber supply in this country. The second phase, relating to all forest resources, will be designed to examine timber, wildlife, water, and recreation; their integrated management; and their future supply. The second conference is expected to draw a much wider constituency, and to lead to more controversial decisions.

This volume gives the current status of knowledge about, and future visions for, the wood resources in our forest. It must be said, however, that the information needed by politicians and decision-makers is constantly changing, and reflects the changes in public values. How long the issues discussed in this proceedings will remain current is anyone's guess. It is hoped that this document will stimulate future discussions and serve as a marker along the way in the continual evolution of Canadian forest policy.

Limits of Federal-Provincial Cooperation, 1920-1936: Ernest Herbert Finlayson and Canadian Forestry

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Abstract

In preparing this paper, I went back to the literature to see what other historians have done in the past. What I found were chronologies of acts and policies being passed, government forestry organizations being founded, and detailed appraisals of constitutional issues surrounding the management of Canadian forests. All very useful material, at least to the historian, and I am sure also to the forester, but it seemed to me that a very important component was missing - the interplay of personalities among politicians, forestry or conservation advocates, and foresters. This took me back to the early 1970s, when discussions were held concerning the possibility of compiling a history of what was then the Canadian Forestry Service. A question posed to me at that time was simply, Who were Canada's equivalents of men like Gifford Pinchot? It has taken the better part of two decades to begin to answer this question. What this paper will do is look at the rather tragic figure of Ernest Herbert Finlayson, Director of the Dominion Forestry Service, 1925-1936, and through his career attempt to analyze the political, social, economic, and constitutional issues that combined to frustrate creative attempts at federal-provincial cooperation during the formative period of Canadian forestry policy.

Résumé

Lors de la préparation du présent article, l'auteur a consulté les comptes rendus de conférences similaires pour savoir ce que d'autres historiens avaient fait auparavant. On a trouvé des listes chronologiques des lois et des politiques ayant été adoptées par les organismes forestiers gouvernementaux qui n'avaient été créés ainsi que des évaluations détaillées des questions constitutionnelles entourant l'aménagement des forêts du Canada. Ces données étaient toutes très utiles, du moins aux historiens et, sans doute, aux forestiers, mais il semblait qu'il manquât un élément très important: l'influence réciproque des policitiens, des défenseurs des forêts ou de la conservation et des forestiers. Ce problème remonte au début des années 70 lorsque l'on discutait de la possibilité de rédiger l'histoire de ce qu'était à l'époque le Service canadien des forêts. On a demandé à l'auteur quels Canadiens pouvaient se comparer à un tel protecteur de la nature comme Gifford Pinchot? L'auteur avait besoin de presque deux décennies pour commencer à répondre à cette question, ce qui explique l'écart entre la tradition et la présente étude. Cet article examine le destin plutôt tragique d'Ernest Herbert Finlayson, le directeur du Service fédéral de sylviculture de 1925 à 1936 et tentera, par l'examen de sa carrière, d'analyser les enjeux politiques, sociaux, économiques et constitutionnels qui se sont conjugués pour contrer les tentatives créatrices de coopération fédérale-provinciale lors de la période aboutissant à l'élaboration de la politique canadienne sur les forêts.

Introduction

On the morning of February 26, 1936, Ernest Herbert Finlayson, Director of Forestry in the federal Department of the Interior left his Cameron Avenue home in Ottawa and disappeared without a trace. Finn, as he was commonly known, enjoyed an international reputation as a capable forestry administrator. Indeed, he was, perhaps , in his idealism, his reformist disposition, and the fervour with which he advocated the cause of forestry and forest conservation, the closest Canadian counterpart to Gifford Pinchot, the renowned American forester, conservationist, and progressive.

Yet, such a reputation was bought at a high price. Finlayson's disappearance cannot be chalked up to just another sad tale of the depression of the 1930s, which drove so many individuals to financial and mental despair. The Department of the Interior admitted that "Mr. Finlayson's condition of health [was] in some measure due to overwork at the time the department was preparing material for the Alberta and Saskatchewan resources commissions when it was necessary to account for twenty-five years of administration of the resources of these provinces" (NAC, rg 32 c2, vol. 608, E.H. Finlayson). Behind this bland bureaucratic statement lay the frustrations and acute disappointments that exemplified the Canadian government's retreat from a broadly based conservation ethic after 1925, and particularly from any creative federal-provincial cooperation to produce a national forestry policy.

Growing up during the American progressive era, Finlayson had been imbued with the popular view that the conservation movement provided a basis for introducing proper planning and utilization techniques to the exploitation of natural resources in support of national development. He saw forestry as an important part of this conservation ethic and had been inculcated by Berhard Fernow, Dean of Forestry at the University of Toronto, with a dedication to public service and the necessity of powerful state activity to achieve forestry goals. He found himself in a strategic position to promote forestry after World War I and set a furious pace in doing so. It was not, however, the weight of success that was to drag Finn down. Vaulted to the position of Director of Forestry in 1925, he was to discover in 11 agonizing years the limits the Dominion government imposed on its forestry activities and the distance that the political leadership of the 1920s and 1930s was prepared to retreat from any useful forestry policies. Thus, starting with great hope and ending in disaster, Finlayson's career offers a unique perspective from which to analyze the ultimate failure during the interwar years to adopt effective federal-provincial cooperation in forestry measures as part of the natural fabric of Canadian public policy.

Early Stages in the Evolution of Federal Forestry in Canada

E.H. Finlayson was born in Toronto in 1887 and graduated from the University of Toronto with a degree in forestry in 1911. There, Fernow had taught both the value of the private "owner's interest" in effective forest management and the need for the enlightened hand of state regulation in guiding private enterprise (Fernow 1903). Summer forestry work had brought Finlayson to the attention of R.H. Campbell, the widely respected federal Director of Forestry, who was seeking bright young professionals to staff positions in the forestry branch. He was appointed in early 1912 to the position of inspector of fire ranging, with jurisdiction over all forest protection work of the Department of the Interior outside forest reserves in the three prairie provinces. (NAC, rg 32 c2, vol. 608) The forestry branch that Finlayson joined was a young and vibrant organization. Federal forestry was a relative latecomer to the field; a permanent office of the inspector of timber and forestry was only set up in 1899. During the prewar period, Ontario and Quebec had been leaders in forest conservation efforts, experimenting with fire protection measures and the establishment of forest reserves since 1883. British Columbia had investigated forestry measures through its Royal Commission on timber and forestry in 1909 and actually established measures patterned after Pinchot's ideas in the United States. Finally, New Brunswick had established both a forest survey and inventory in 1914 and a forestry service to manage it (Gillis and Roach 1987).

The federal government had chosen, at first,only to emphasize tree planting in the prairie west. The popularity of more efficient and scientifically based management techniques with the federal bureaucracy and the public as a whole towards the end of the 19th century, however, persuaded the new Liberal government of Wilfrid Laurier to undertake a more thorough forestry program under the auspices of Clifford Sifton, the dynamic Minister of the Interior.

The Laurier government appointed to the position of inspector a land surveyor and unsuccessful Liberal candidate, Elihu Stewart. Despite the partisan nature of the appointment, Stewart proved to be an excellent choice. He took an expansive view of federal forestry that saw the forestry branch as a progressive force in introducing scientific ideas concerning planned and efficient resource management to Canada. Stewart moved rapidly beyond the role of tree planting to advocating that the branch's jurisdiction be extended to forest fire protection, inventorying resources, classifying timberlands, and controlling leasing and cutting regulations. As well, forestry research was identified as a national responsibility that the branch could undertake in all areas of the country. To support these ideas and to promote forest conservation in Canada, Stewart and his successor, Campbell, established the Canadian Forestry Association in 1900. This was a unique amalgam of business and political leaders from all parts of the country who served a dual role as lobbyists for forestry measures and as an advisory body to the federal government (Gillis and Roach 1986).

Unfortunately for forestry advocates, the Laurier government's support for forest conservation had definite limitations. Western public opinion was not particularly favourable to extensive, centralized controls over access to all federal western timberlands. They would accept some reservations, but preferred to deal with the more lax federal timber, mines, and grazing branch, which had handled timber leases from 1881. Thus, although forest conservation proved to be a popular concept in Canada during the first decade of this century, especially among eastern, urban voters, which the Laurier Liberals could not ignore, it was also an issue to which the government was not, in deference to its western wing, prepared to give full-hearted support.

Both the Forest Reserves Act of 1906 and the National Parks Act of 1911 reflected political compromise. Basically, the forestry branch was given control over specific forest reserve areas, which were created by the 1906 act and enlarged in 1911, and responsibility for fire protection on all western lands. This partially satisfied conservationist calls for a start on land classification, better management practices on reserved areas, and increased fire patrols. On the other hand, administration of all forestlands outside the reserves and all licensed berths then existing within the reserves was left with the timber, mines, and grazing branch as a salve to business and settler opinion in western Canada. It was a silken glove that served to rein in the ambitions of the forestry branch while appearing to promote the idea of forest conservation (Gillis and Roach 1987).

The Dominion Forest Reserves and National Parks Act of 1911 also confirmed another trend in the early conservation movement in Canada. It established a separate national parks branch that continued the ongoing fragmentation of the conservation movement into various components, some utilitarian in approach and others more preservationist in orientation (Van Kirk 1969). This trend was inevitable given the growing speciality of disciplines surrounding such areas as wildlife, flora, water, public health, and forest management, all of which were considered to fall under the general rubric of "conservation" of national resources.

The Laurier government, and later that of Robert Borden, created a host of new responsibilities and organizations concerned with conservation to cash in on the popularity given the cause by United States President Teddy Roosevelt and associates like Pinchot. The forestry branch, however, found its role as the central conservation agency diminished, especially after the formation of the Canadian Commission of Conservation in 1909. This body was set up as a result of international meetings between the United States, Canada, and Mexico under the sponsorship of Roosevelt. It was an advisory body with the responsibility to investigate and inventory resources and make recommendations on how they should be developed and utilized (Smith and Witty 1970; Pinchot 1972). Its chairman was Clifford Sifton, whose energetic leadership soon had the commission undertaking an ambitious program. Its legislation unfettered the commission from constitutional niceties and enabled it to cooperate easily with provincial governments and private industry. In this way, it moved into the fields of silvicultural research and inventorying provincial resources over which federal foresters thought they had a leadership role; a good deal of friction resulted.

The Early Career of E.H. Finlayson in the Federal Forestry Branch

It was into this milieu that Finlayson stepped in 1912 and he quickly became a convert to the forestry branch view of the issues involved. In 1914, as a result of reorganization and in recognition of his talents and, perhaps, good Tory connections, he was placed in charge of the Alberta inspectorate, with control over the various Rocky Mountain reserves, the most important field position in the branch (NAC, rg 32 c2, vol. 608). In February 1920, Finlayson was transferred to Ottawa as Chief of the Forest Protection Division. Shortly thereafter, he found himself nominated as the federal representative to the first British Empire Forestry Conference, held in London, England, in the summer of 1920. This was to be a major turning point in his career.

The forestry conference was a prestigious event. It followed from the Wartime Dominion's Royal Commission that had toured the empire gathering information on supplies of natural resources. It was convened by the newly formed British Forestry Commission to gain information on the forest resources of the empire, to determine strategic supply areas, and to encourage their proper management. In addition to Finlayson, the Canadian delegation was comprised of prominent forestry men: Robson Black, Secretary, Canadian Forestry Association; Clyde Leavitt, Chief Forester, Conservation Commission; Ellwood Wilson, Chief Forester, Laurentide Paper Company; Avila Bedard, Assistant Chief Forester, Province of Quebec; and Martin Grainger, Chief Forester, British Columbia (NAC, rg 39, file 40129). The program of the conference concentrated, aptly enough, on the responsibility of the state for forestry policy, organizing forest authorities, management techniques, and, of course, the extent of imperial timber resources. These were questions that Finlayson had been ruminating about since 1914 and, on his return to Canada, he set down a report that succinctly analyzed the basic weaknesses in federal and provincial forestry organization. Though it remained an internal document, the report set an agenda for the forestry branch in the early 1920s and launched Finlayson as an important spokesman within the federal government on forest conservation matters.

The report made the usual claim for a single forest authority to manage western federal forestlands on a scientific basis. However, it also levelled scathing criticism at the Commission of Conservation. Finlayson was particularly critical of the forest inventory work conducted by the commission in British Columbia, Ontario, Nova Scotia, and New Brunswick, as well as silvicultural and other research projects carried out in cooperation with New Brunswick and Quebec. He worried that the commission, as an advisory body, would erode the branch's position as the national forestry authority and, consequently, contribute to a curtailment of its mandate and funds (NAC, rg 39, Finlayson report, file 40129).

Finlayson was only joining a growing chorus of critics of the conservation commission, which was to fall afoul of the union government in 1921 over development of hydroelectric power on the St. Lawrence River system. Arguments put forward by Finlayson about duplication of services and cost savings were to be marshalled along with other petty bureaucratic fuming to bring about the commission's demise (NAC, rg 22, vol. 6, Report of Council on Conservation Commission). The forestry branch rushed to share the spoils and assume new obligations. Forestry took over the defunct body's surveying and inventorying activities, as well as its silvicultural and forest insect research projects. The new obligations arose from the cooperative nature of much of this work with various provinces and private corporations. Its continuance would require a negotiated basis by which federal assistance could be channelled into provincial jurisdictions. Finlayson had come to believe that such cooperative arrangements were essential for an effective national forestry policy, but time would prove this to be a most difficult conundrum for him to solve.

With its new responsibilities, the forestry branch moved quickly to reestablish itself as the single national voice on forestry and forest conservation. R.H. Campbell set out four initiatives that the branch would pursue in developing a national forest policy: improvement, protection, and expansion of western forest reserves (totalling 23 million acres (9.3 million ha) in 1921); development of a nationwide research program emphasizing cooperation with industry and provincial governments; a national forest inventory; and public education on forestry issues (NAC, rg 39, Campbell correspondence, file 40129). A political embarrassment for the Liberal government of William Lyon Mackenzie King, which had defeated Meighen's Unionists in 1921, was to provide the impetus to keep reform of federal forestry measures on centre stage.

The issue was the contentious matter of shipping unprocessed timber to the United States. Most provinces already controlled the export of unmanufactured wood cut on Crown lands and successive federal administrations had been careful to stay clear of the thorny issue. At stake in this case, however, was pulpwood cut on private lands. Basically, pulpwood cut on settlers lands in marginal farming areas of eastern Canada was a prime source of supply to newsprint manufacturers both in Canada and in the United States. Canadian manufacturers were convinced that the American trade forced up the price of settlers pulp and aided foreign competitors. They elicited the services of a timber broker turned publicist and self-proclaimed conservationist from Atlantic Canada, Frank J.D. Barnjum, who, through connections in the Liberal business community in Montreal, finally persuaded the King government to prohibit the export of pulpwood in June 1923. (Canadian Annual Review 1923).

Immediately, the government began to realize the size of the hornet's nest it had kicked. Prime Minister King backtracked in the face of criticism over interference with property rights and public rumblings from Premier Taschereau of Quebec on the effect of the ruling on the colonization movement in that province. King quickly opted for the time honoured approach of a Royal Commission to fully investigate the extent of pulpwood supplies, the location of pulp manufacturing, and the appropriateness of the embargo and to make recommendations concerning the conservation of pulpwood supplies. The work of the commission is interesting in itself, but what concerns us here is that Finlayson was appointed its secretary. He was an excellent choice because he could articulate a conservation stance independent of Barnjum's and the Canadian manufacturers' viewpoint.

Finlayson wrote the final report. It provided an escape hatch for the King government from the embargo fiasco and made an articulate plea for better forest management practices across the country. The government responded by allowing the embargo provision to die and then seized the political advantage by announcing its intention to embark on a new national forestry policy aimed at the preservation of Canadian forests (NAC, rg 39, Proceedings of the Royal Commission on Pulpwood; Canadian Annual Review 1924-1925).

Finlayson Becomes Director of the Federal Forestry Branch

Finlayson was rewarded for his work on the commission by being confirmed as Director of Forestry in 1925. King's Minister of the Interior, Charles Stewart, was regional representative in the cabinet for the western prairies and a low tariff man with a strong belief in the development of Canadian resources. He became interested in and committed to forestry measures, but, unfortunately, he did not enjoy King's confidence and this would make him a pawn rather than a power broker in future political events in the late 1920s, which would gravely affect Canadian forestry (Neatby 1967). In 1924, however, a crucial factor in developing a new forestry policy was to secure federal-provincial agreement on how to deal with problems such as fire protection, the forest inventory, and the dedication of lands to sustained forest production. To begin this process, Stewart and Finlayson convened a federal-provincial meeting in Ottawa in January 1924. Fire protection was chosen as the subject of the conference because of its noncontroversial nature. All provinces accepted the need to carry out such activities. The problem was, as Finlayson pointed out, to convince governments that such protection was not an end in itself, but a method of securing further forestry investments in timberlands.

The provinces, for their parts, were facing expenditure and taxation problems that made them willing to discuss measures that might relieve the costs of maintaining their forests. Stewart's opening address to the conference gave them reason for some hope in this regard. He began with a call for cooperation in fire protection matters that would "bring about some degree of uniformity throughout the country in regard to the preservation of forests". He went on to suggest that the federal government was tentatively considering to aid this process through financial assistance for fire protection. Furthermore, Stewart said that although federal officials considered forest disease and insect control as provincial matters, the government might also consider assistance in these areas as well. Basically, a new fiscal arrangement for forestry in Canada was being proposed and this issue overshadowed all other discussions at the conference (NAC, rg 39, Proceedings of the Dominion-Provincial Conference on Forest Fire Protection). It was rudimentary in nature, but the proposal envisioned a forestry aid system for Canada similar to that existing in the United States where the federal government contributed to state programs. The Weeks Act, on which this American scheme was based, had been studied by

Finlayson and other federal forestry officials and was deemed an essential pillar for Dominion-provincial forestry relations in Canada.

Only Ontario, represented by J.J. Lyons, Premier Howard Ferguson's Minister of Lands and Forests, seemed confident that his province could do without help and interference from the federal government. Other, less wealthy provinces saw benefits from the scheme if they could maintain independence of action. They wanted immediate financial aid to purchase fire-fighting equipment, improve trails and other facilities, and to underwrite air patrol operations. The federal government was indicating that it could offer some such support, but remained vague on its nature (i.e., whether it was direct aid, services, or something else). In return for aid, however, the federal government wanted greater provincial activity in classifying areas as forestlands and in undertaking management arrangements for these areas. This was Finlayson's formula for federal leadership in forestry. The provinces were too canny to surrender this much independence over their actions and were only willing to recognize land classification as a worthy objective to be strived for on no set timetable.

The best that could be agreed upon was a commitment to hold further conferences to discuss the bases for an agreement. Stewart betrayed the federal governments lack of clear direction in his closing remarks when he indicated that he was willing to listen to provincial proposals, but held out little hope for direct Dominion assistance in areas of purely provincial jurisdiction, such as fire fighting and reforestation. Rather, he claimed that his original remarks had been aimed at "points of contact" between the two levels of government , though Stewart did not stipulate clearly what those might be (NAC, rg 39, Proceedings of the Dominion-Provincial Conference on Forest Fire Protection). The federal government may have underestimated the ability of the provinces to unite in support of forestry initiatives and now feared being stampeded into an assistance scheme dictated by the needs of others. The net result of the conference was some federal support for air operations and publicity campaigns such as "save the forest week."

These were modest gains, but they did reflect the good personal relations enjoyed by the small group of foresters across the country. Such cooperation bespoke of the possibilities of a more creative federalism in this field. At the political level, however, the constitutional position during the 1920s and 1930s was that forestry was almost exclusively a provincial responsibility and should not benefit from direct federal aid. This was a position that constrained the possibilities for innovative federal-provincial solutions until after World War II, when the Rowell-Sirois Royal Commission on federal-provincial relations was finally acted upon (Armstrong 1981). Without the gift of divination, however, Finlayson was buoyed by the chance of further cooperative efforts. This confidence was increased by King's apparent support for the final report of the pulpwood commission, which was tabled in early 1925. This was accompanied by efforts at the federal level to promote a larger role for the newly named Dominion Forestry Service in managing operating timber berths, first in the pulpwood selection area in Manitoba, but with plans to extend the arrangement to other areas (NAC, rg 39, vol. 248, file 28829).

The Loss of Federal Initiative in Western Forestland

By 1926, Finlayson was to find how fleeting this progress was to be and how chimerical was the King government's commitment to forestry. It is not overly cynical to suggest that the Liberals had moved rapidly on the recommendations of the pulpwood commission because they were facing a general election in 1925. Forestry remained a preelection commitment and a likely field for popular measures. Stewart, however, did not have enough pull in cabinet to obtain approval for any type of strong forestry policy. When it was announced in June 1926, the policy dealt only with western lands and was not very adventurous. Rejecting artificial planting and regeneration techniques, it responded only to Finlayson's desire that the western forest reserves be extended until they included all non-agricultural lands in the west suitable for timber growth. The government also declared its intention to regulate cutting on such lands to ensure natural regeneration. This was a good deal less than a truly national forestry program and even this limited approach smacked of a sham because no timetable was announced and actual forest reserve lands had shrunk from 23 million acres (9.3 million ha) in 1921 to 21 million acres (8.5 million ha) in 1926. The policy did have its desired political effect, being welcomed in the press as an emulation of the European experience where "expert foresters... take off only so much timber as can be removed without weakening the vitality of the forest," but the director would have agreed with those news reporters who warned that this policy was "only as good as the progress the government makes toward reaching [its] objective" (NAC, rg 39, vol. 271, file 40139-II).

It rapidly became obvious to Finlayson that progress in implementing the new policy would be nonexistent; indeed, the King government's infatuation with forest conservation ended in 1926 to be replaced by disinterest and a desire to abdicate, as much as possible, any federal role in this field. The policy disappeared in the political crisis known as the King-Byng affair (Graham 1967). In the federal election of 1926, King returned to power with a majority, Stewart as his Minister of the Interior, and a new set of political priorities. A major goal was to reach a settlement with the prairie provinces for handing over control of western natural resources, including timber, to strengthen the Liberal party politically and, in part, as an economy measure.

These new priorities conflicted directly with Finlayson's own goals to expand and redefine the mandate of the Dominion Forestry Service. It was in the period leading up to the resource transfer agreements that Stewart's lack of stature with King jeopardized the service's ability to make its case effectively to the Prime Minister. All cannot be blamed on the Minister of the Interior, however. Finlayson also had a blind spot for the resource transfer issue. It had been a growing problem since the end of World War I. Among many Canadians, there was a feeling that the Dominion's purposes in western Canada had been fulfilled. The land had been settled; the railways built, if not overbuilt; and the provinces created. The western provinces were adamant in wishing equality of status. They found themselves pressed for money for local improvements and were sure that management of their own natural resources could generate these revenues. At the same time, pressure festered at the federal political level. National parties lay shattered in the wake of the conscription crisis; regionalism was rife and a general disillusionment had set in. In western Canada, the progressives, a fragmented farm protest movement that had grown to prominence during the war years, saw the resource issue as important. King set as one of his primary tasks the rebuilding of the Liberal party through reintegration with the progressives, many of whom were disenchanted grits. Therefore, at various times after 1922, King offered the transfer of western resources as part of a political package that would gain this end, though the Prime Minister's terms were not particularly generous (Martin 1973).

Perhaps these difficulties lulled Finlayson and others in the forestry service into a false sense of security. Attached to the "purchase theory" for Rupert's land, which likened the acquisition of the public domain in the Canadian west to that in the United States, they argued that, even if some lands were turned over to the western provinces, extensive timberlands must be retained under federal ownership to accomplish national goals in conserving wood supplies and promoting proper forest management techniques (Rubin 1931). King, however, subscribed to the more legally sound position that the western provinces had a constitutional right to the control of their resources based on the British North America Act. In the desultory federal-provincial negotiations of 1922, this rejection of the American model did not have much impact because the federal position had included control over western timber. After the political crisis of 1926, the Prime Minister desperately wanted western political support and the situation was to be different.

King was particularly interested in a coalition with Premier John Bracken's progressives in Manitoba. Bracken was willing to deal, but he wanted the resource question settled first. In July 1928, with both a political coalition and a resource transfer agreement on the table when Bracken travelled to Ottawa, King was more disposed to be reasonable. Manitoba was given control over much of its natural resources, including the Dominion forest reserves. All that remained was for a proposed Royal Commission to determine a suitable financial settlement between the two governments (Kendle 1980). Suddenly and dramatically, the ground on which the forestry service had built a substantial part of its mandate was radically altered. At the political level, the draft agreement was greeted favourably and there was nothing the forestry service could do but fight a futile rearguard action to stop the Manitoba formula from being adopted elsewhere.

King, for his part, had not come to the end of his political manoeuvring. Happy with his success with Manitoba, and not immediately able to extend this automatically to Saskatchewan and Alberta, the Prime Minister turned to British Columbia. There, the railway belt ran through the heart of the province. Most of this area was largely inaccessible forestland that had not been taken up either by the railways or for settlement. Several forest reserves had been established in the belt and more were planned. The British Columbia government was interested in taking over administration of the area again, but a federal Royal Commission on the reconveyance of land to British Columbia had declared in 1928 that the province had no right of ownership (Neatby 1967). The Prime Minister now offered up the railway belt to steal a march on the Tories in British Columbia.

Finlayson realized that if the forestry service was to make a stand it would be in the railway belt where there was no doubt about federal ownership of the land. An effort was made to intervene in the political gamesmanship with proposals for clauses in the transfer agreement that would preserve federal control over substantial national forest areas in the belt. The service contended that

> "the primary value and function of the national forest areas is to meet...[a] future emergency. Under present conditions, even in the eastern provinces where forest revenues are higher and where market values are greater, the local authorities have found themselves unable to take the necessary precautions in this condition (sustained yield), although Ontario and Quebec are now taking initial steps in that direction.... It appears, therefore, a foregone conclusion that the prairie provinces, at any rate, would find themselves unable to carry on the protection and administration of these national forest areas to the extent to which their importance in the national interests demands."
> (NAC, rg 39, vol. 95, file 48183)

As for the west coast reserves, British Columbia had argued in the recent past that at least part of its forest should be regarded as a national resource and be administered at federal expense. These arguments had some impact and plans were made for the reservation of four substantial national forests in British Columbia. Finlayson was confident that a truly national role for the forest service had finally been recognized, particularly as it would also assume responsibility for two research stations in British Columbia - one on the coast and the other in the interior (NAC, rg 39, vol. 95, file 48183).

Once again, however, all had been done without due regard for the necessities of politics. By late 1929, it was obvious that everything was becoming unglued. On the broad front, the final negotiations for a resource transfer agreement with Manitoba were completed. The only mention of forestry was a federal admonition that the province provide for professional care of its forests. With another federal election looming in 1930, King signed away the railway belt with none of the conditions requested by the forest service. The Prime Minister's only regret was that he could not persuade Alberta to cash in on a federal offer to turn over control of its natural resources. The actual agreements with Alberta and Saskatchewan were to drag into the 1930s and were eventually ratified by the new Tory government of R.B. Bennet. King, however, claimed credit for all the deals. His biographer claims that they were probably the major achievement of the Prime Minister's third administration (Neatby 1967).

The propriety of the natural resources transfer cannot be doubted or criticized. The west had been settled and there was no reason to treat these provinces on any different constitutional basis than any of the others. There was, however, in the case of forestry, a lack of vision, understanding, and, it must be added, competence. Examples of cooperative forestry measures were put before the politicians by Finlayson and his officials time and again and the promise of a creative federalism in this area was examined extensively. It would appear that provinces such as Saskatchewan, Alberta, and British Columbia may have been easily persuaded to leave substantial reserves under federal control to aid both forest research and experimental work, and timber conservation and watershed protection objectives. This is not to say that federal administration was inherently superior to provincial control, but that federal forests would have continued to give a legitimate federal-provincial cast to forestry that could have broken the constitutional logjam for a national forestry program. The King government was incapable of recognizing or grasping that challenge.

Defining a Federal Role in Forestry

Charles Stewart attempted to place the best light on the new situation by picking up the theme of "points of contact" enunciated in 1924 by developing suggestions concerning inventorying and surveying forest resources. This was considered a suitable area for federal-provincial cooperation because there was thought to be little room for squabbles over jurisdiction and fiscal arrangements, but scope for some federal leadership through logistical support and coordination. Pressed by the ever-present advocate of forest conservation, Frank J.D. Barnjum, to hold another federal-provincial forestry conference, Stewart convened a national conference on inventorying forest resources in June 1929 (NAC, rg 39, vols. 267-268, file 39766). Once again, the provinces proved eager to discuss forestry matters. Stewart was careful to steer clear of the assistance issue and also retreated from previous federal suggestions for standardized regulations and other forestry measures through Ottawa's auspices. His key proposal was for an immediate role for the federal authorities in coordinating a total forest inventory for the whole country and compiling the results. Stewart then turned the meeting over to Finlayson, who was showing signs of tension and exhaustion from the battle over the resource transfer question, to attempt to reach an agreement on a national inventory project (NAC, rg 39, vols. 267-268, file 39766).

For their part, the provinces, many of which were already undertaking some inventory work, wanted federal assistance, guaranteed to the end of the project, if they were to be subjected to any federal timetable. It was a refrain provinces such as British Columbia, Quebec, and New Brunswick were to repeat again and again until the 1940s. Finlayson was in no position to commit resources; thus, he had to be flexible on the matter of the timetable. It was on this point that the conference really foundered. The provinces were supportive of greater federal leadership in forestry, urging the continuance and expansion of federally sponsored work in silvics, forest reproduction, regeneration, and insect and disease control, but they desired direct aid. Even without the latter, however, they were still willing to push harder on their inventory work, under similar standards and procedures, with the objective of completing it in 5 years and delegating to the forest service responsibility for collating and analyzing the information collected (NAC, rg 39, vols. 267-268, file 39766).

This conclusion from the conference must be viewed as being significant in a period when the concept of federal-provincial cooperation was just beginning to emerge. It appears to have been Finlayson's stature among Canadian forest administrators and the general desire from this community for federal leadership in these matters that pushed forward cooperative arrangements, even on a limited basis, in the face of federal political disinterest. Nevertheless, the modest success of the conference could not mask the fact that federal forestry had been dealt a body blow by the natural resource transfers. Indeed, Stewart's renewed interest in the national inventory was, in part, political because the Liberals were facing another election in 1930. He was trying to answer critics in the Canadian Forestry Association and the Canadian Lumberman's Association who suggested that the government had virtually abandoned any meaningful forestry policy. (Regina Leader, Feb. 18, 1930). In response, Stewart, in what turned out to be his last major statement on forestry matters, lectured to the Canadian Lumberman's Association that the era of "migration" and "mining" the forest was over and requested its support for land classification and forest inventory work carried out by the Dominion and provincial governments as the essential basis for preparing management plans based on the principle of sustained yield.

Such statements had a hollow ring from a government that was in the process of relinquishing control of its own forest reserves. Finlayson, however, could not afford to play down this evidence of support. He needed to find responsibilities for the forest service independent of the reserves. The inventory was one project and the other was research. His attention was drawn to the McSweeny-McNary Act in the United States, which underwrote a long-term program of forest research that included soil analyses, silvicultural techniques, economic trends, and product research. W.M. Robertson, who analyzed the situation, recommended seven Canadian research stations, roughly encompassing provincial boundaries and forest types (NAC, rg 39, vol. 95, file 48143). Finlayson persuaded Stewart in mid-February 1930 that it would be politically advantageous to announce that forestry research would form an important part of the mandate of the forestry service after the transfer of the western resources. This statement evoked great hope amongst forestry advocates because the function was compared with that given to the department of agriculture, which constitutionally and legislatively was a federal responsibility. Thus buttressed, Finlayson produced a major policy paper entitled "Federal forestry functions after transfer of the national resources," which set out a mandate for silvicultural research and maintenance of research stations, a function it was argued the provinces did not have the money to perform adequately; coordination of the national inventory and collation of the results; and technical research and the establishment of national standards in areas such as fire fighting, disease and insect control, and the development of forest working plans (NAC, rg 39, vol. 95, file 481:3). It was a much more specific and much less sweeping mandate than that of the early 1920s, but Finlayson remained optimistic that he could sell these initiatives to a reluctant Liberal government.

Finlayson was concerned that the loss of western forest reserves would also entail disbandment of the field staff. The new policy would need this staff and Finlayson marshalled his facts and political acumen to take advantage of an impending federal election to push the new policy and the agreements reached at the inventory conference. Once again, however, he had figured without considering Stewart's essential irrelevancy to the situation. In the face of Finlayson's policy paper, W.W. Cory, Deputy Minister of the Interior, still indicated that he wished to serve Liberal preelection cost-cutting objectives by not only releasing the service's field staff but also reducing headquarter's programs as well. It was this chilling fact that finally drove home the message that despite all the ministerial statements of policy and good faith, the Mackenzie King Liberals, convinced that forestry was purely a provincial responsibility, and with a wish for economy, were bent on curbing dramatically this field of activity in preparation for the 1930 election.

Plans on both sides came to nought as the Liberals went down to electoral defeat. An increasingly disturbed and brittle Finlayson tried to use Tory connections through his half brother, William Finlayson, Minister of Lands and Forests in the Henry government in Ontario, to convince the new Prime Minister, R.B. Bennett, to support forestry policy. However, the program carried a hefty price tag for the time - $500,000 - and, facing the brunt of the depression, the government was determined to slash expenditures. Finlayson saw his organization reduced to barely 30% of its size in 1924. The only small ray of hope during the early 1930s was an effort through a body called the National Conservation Council to foster federal-provincial cooperation and the designation of various research areas in cooperation with the governments of New Brunswick, Manitoba, and British Columbia, as well as the Department of National Defence (Department of the Interior 1934).

Finlayson became more and more depressed. He was dispatched to the empire forestry conference in South Africa in the summer of 1935 for a rest. On his return to Ottawa, he found Mackenzie King back in power. Thomas Crerar, the new Minister of the Interior, announced shortly after taking office that the government would undergo reorganization and it soon became known that the forestry area would be reduced in stature rather than enhanced under the new arrangements. Indeed, the Canadian Lumberman's Association was led to observe that the federal government had effectively withdrawn from managing one of the country's most important resources (NAC, rg 39, vols. 267-268, file 39766). For Finlayson, the time came to leave one February morning; he departed from his home and never returned.

Ernest Herbert Finlayson is a tragic figure. He entered government service with an idealist vision that the state could use the tools of scientific resource management to promote efficient and enlightened utilization of those resources in support of national growth and development. He became imbued with the conservation ideas of American progressives such as Gifford Pinchot and the forestry model produced by them, which involved both federal control of large forest reserves and financial support for forestry activities. During the period after 1920, Finlayson attempted to bring these ideas to fruition. Though he appreciated the extent to which basic management and silvicultural techniques must underpin forestry operations, he also realized that Canada needed the essential structure of a national forest policy before the other goals could be met on a national basis. Finlayson was convinced that such a policy should involve federal control of substantial western timberlands, which could be managed for future generations; federal funding and active participation and leadership in forest research; and federal-provincial cooperation in fields such as forest inventorying, fire protection, land classification, and reforestation. Such leadership, in his mind, involved direct federal financial assistance. These were visionary ideas, many of which eventually found their way into the Canada Forestry Act of 1949.

Finlayson found his idealism and dedication totally frustrated by the political realities of the 1920s and 1930s. Beginning with the King government during the period after 1925, there was a broadly based retreat from the active forestry ethic that Finlayson cherished. Abandonment of the western forest reserves, followed rapidly by drastic cuts in government activities as a result of constitutional niceties and then the depression, served to totally dash his hopes. His bitterness that Canadian governments chose the way of political expediency rather than that of creative policy and leadership knew no depths. The most apt comment on this period comes from D. Roy Cameron, Finlayson's assistant and, then, successor as Director of the Forestry Service, in a memorandum to his political superiors: "there is undoubtedly a great need for real leadership in forestry affairs in this country. That leadership, to be effective, must come from sources much higher than any departmental officer.... It is equally true that the remedy [to conflicting jurisdictions] can be alone in coordination...under Dominion auspices" (NAC, rg 39, vols. 267-68, file 39766). Much of these observations remain equally true today, but a world war and major reshaping of federalism through reaction to the recommendations of the Rowell-Sirois Royal Commission lay between Canadian forestry and even a glimmer of hope for solutions to the problem of "conflicting jurisdictions" and any creative approach to federal-provincial cooperation.

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Current Policy Directions

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Abstract

A distinction is made between a policy and a statement of position on an issue. Factors that normally influence the formulation of policies are those of existing conditions and perceptions as related to past experience. This almost inevitably renders them inadequate to deal with the future. The focus in this paper is primarily on government policies, but those of the forest industry and other groups are relevant. It is suggested that there are several tests that can be applied to ascertain whether a policy is effective. Can it be readily implemented to achieve desired goals? Can it be readily amended or terminated as may be appropriate ? Is it seen to be credible by those who are affected by it, those who implement it, and those who believe they have a right in its determination?

Policies that deal with Canada's timber resources have to recognize the elements of forestland, capital, and investment, both human and nonhuman; institutional arrangements; the market place; and society's goals and objectives. The recognition may be explicit or implicit, but either way should be evident. There are five generally accepted subject areas that are currently considered to be important by the forestry sector: multiple use and resource management, sustained yield and sustainable development, forest tenure and forest management, Canada's forests for world timber markets or for domestic markets and tourism, and zoning the land base for timber production. The adequacy of existing policies with respect to addressing these issues is in question, particularly in view of society's changing perceptions of and values attached to the forest. Policies that are formulated to deal with these issues must provide a framework of certainty for those responsible and accountable for the forest resource and its management. In so doing, the greatest challenge is to set in place a credible process to establish such a policy framework.

Résumé

Le présent article établit une distinction entre une politique et un énoncé de principe en vue d'une question. L'élaboration des politiques est généralement influencée par des facteurs liés aux conditions actuelles et à des perceptions qui découlent de l'expérience antérieure. Cela les rend presque inévitablement inaptes pour aborder l'avenir. Cette étude porte principalement sur les politiques gouvernementales, mais s'applique également à celles de l'industrie forestière et d'autres groupes. Plusieurs questions peuvent servir à vérifier l'efficacité d'une politique. Peut-elle être facilement mise en œuvre pour atteindre les objectifs visés? Peut-elle être facilement modifiée ou abrogée, selon le cas? Les personnes qu'elle touche, les responsables de sa mise en œuvre et ceux qui sont persuadés qu'ils ont voix au chapitre la jugent-elle digne de foi?

Les politiques relatives aux ressources forestières du Canada doivent tenir compte des éléments suivants : les terrains forestiers, le capital et l'investissement, tant en ressources humaines que non humaines; les ententes institutionnelles; le marché; ainsi que les buts et objectifs de la société. Cette reconnaissance doit être clairement explicite ou implicite. A l'heure actuelle, le secteur forestier accorde généralement de l'importance à cinq grands domaines : intégration des utilisations et gestion des ressources, rendement soutenu et développement durable, tenure et aménagement forestiers, importance des forêts du Canada sur les marchés internationaux et nationaux de même que pour le tourisme, et affectation de terres (zonage) à la production forestière. La pertinence des politiques actuelles à ce sujet est remise en question, notamment à la lumière de l'évolution des perceptions et des valeurs sociales de la forêt. Les politiques qui sont élaborées à cet égard doivent donc fournir des fondements solides aux personnes responsables des ressources forestières et de leur gestion. Pour ce faire, le plus grand défi sera de mettre sur pied un processus digne de foi pour établir un tel cadre politique.

Current Policy Directions

Policy is defined as "a course of action adopted and pursued by a government, party, or person." This paper will focus primarily on government policies, but those of other parties, such as the forest industry, labour, and professional foresters, are also relevant. The definition is explicit, but there are many who confuse "policy" with a statement of "position," particularly as related to a current issue.

A statement of policy, as opposed to one of position, should enunciate the principles that are to govern a course of action towards defined objectives. In our society, the formulation of policies is normally developed in the crucible of existing conditions and perceptions. Those individuals or parties involved in the formulation process customarily draw upon their past experiences. This is the "rearview mirror" approach and it ensures that such policies will have a built-in inadequacy in the manner in which they address the future. For the most part, present government policies respecting Canada's timber resources are expressed in legislation that not only reflects the past but also in no way anticipates present forces and demands of society, not the least of which has been that of legal challenge.

Currently, there are five subject areas of major importance in the consideration of policy directions:

1. Multiple use and integrated resource management
2. Sustained yield and sustainable development
3. Forest tenure and forest management
4. Canada's forests for world timber markets or for domestic markets and tourism
5. Zoning the land base for timber production

These subject areas are not in any order of priority, nor are they exclusive, but they embrace many of the issues that face the forestry community when considering Canada's timber resources. To a large degree, existing government policies, as expressed in legislation, do not specifically address many or all of these subject areas or their issues because the policies were formulated in an historical context in which the issues did not exist, or were perceived differently. Allocation of harvesting rights and administrative and regulatory measures relating to the forest were the prime matters with which policies were concerned. They are still important, but they are now seen by many individuals or groups as being inadequate, if not inappropriate.

Historically, the forest was an asset to be exploited as a static or nonrenewable entity for the benefit of society. What has happened over the last 20 to 30 years is that the forest industry and the provincial governments have recognized that forests can be managed as dynamic production systems in a professional and businesslike manner, primarily for timber, but also and sometimes grudgingly for nontimber, values and uses. The recognition has been uneven, but it represents a dramatic shift from the past. Beginning in British Columbia with tree farm licences and in Alberta with the first Forest Management Agreement in 1954, legislation in the majority of provinces has either been amended, as in Manitoba and Ontario, or been redrafted, as in Quebec and New Brunswick, to place responsibility for forest management on public forestlands on the licensee.

The specific arrangements have varied, particularly with respect to the manner in which obligations and funding occur. As a result, however, forest management practices have been initiated or extended to an unprecedented degree. This has resulted in planning and melding of harvesting and other silvicultural activities in a professional way that has been little comprehended by the public at large, or for that matter by many politicians.

At the same time, in the public arena concerns and issues, legitimate or otherwise, have been fueling changes on an ad hoc basis rather than on a considered, objective, and knowledgeable basis. Many of these concerns and issues have collectively been placed under the umbrella of "environmentalism," but this does nothing more than contribute to the muddle of discussion. Essentially, three specific items lie at the base of the concerns and issues. These are land and resource ownership, land and resource use, and management practices. Existing policies, explicitly or otherwise, are based on this tripod. Crown forestland ownership, timber rights as expressed in licences and regulations, and ground rules governing practices are the means by which those policies have been implemented. Until recently, these policies and their implementation were matters between government on the one hand, representing the public owners, and the forest industry on the other hand, representing the timber users and latterly the forest managers. On both sides there was a degree of *certainty* that existed. This is not to suggest a static or moribund state, or that differences and disagreements did not exist, rather, that in terms of the forest and the marketplace for forest products, both the time frame and the dynamics of each were mutually understood.

This relationship of *certainty* is undergoing a series of challenges that must be addressed if an economically viable forest industry is to be sustained. Herein lies the foremost premise. The Canadian forest is a sustainable asset that when managed for timber products can continue to be one of the major sources of social and economic well-being for all citizens. This in no way precludes its use for other nontimber products and values, but recognizes that many of those products and values, such as wildlife and recreation, can be enhanced by appropriate forest management. There are large areas of the Canadian forest that already have been set aside for nonconsumptive uses and where timber harvesting specifically has been prohibited. Increasing such areas carries with it an obligation, as expressed in Recommendation No.19 of "A National Forest Sector Strategy for Canada": "...that allocations to exclusive uses be subjected to rigorous cost/benefit analysis, and the loss of supply through reallocation or withdrawal of commercial forest levels be offset where practicable by more intensive management on the remaining forests." Although the strategy and its recommendations were endorsed by all governments and a number of nontimber groups, this recommendation has subsequently been largely ignored. I use this as an example of where a strategy or policy without commitment or expressed means of implementation is nothing more than words on paper and does not provide any *certainty*.

Thus, any policy should be subject to tests of effectiveness. The first test is whether or not it can be readily implemented to achieve desired goals. A second test is whether it can be readily amended or terminated as may be appropriate. Third, is it seen to be credible by those affected by it, those who implement it, and those who believe they have a right in its determination? The degree to which any policy meets these tests will reflect the degree to which it is likely to meet its objectives and provide *certainty* to those affected by it.

Current policy directions are surrounded by flurries of factors that society, generally, and certain groups within it, is raising daily. Setting aside the issues of land ownership and the markets for forest products, there are sets of "values" being placed on the forest and forest activities that, although not new in themselves, are now being used to influence, if not determine, both the extent and nature of timber and forest management practices. Concern for the intrinsic values of a forest and the misapplication of the concept of "ecosystems" has resulted in demands to restrict both the area for forest management and the nature of forest management practices. The large-scale setting aside or "preservation" of forests and the inappropriate substitution of selection harvesting for clear-cutting are two obvious examples.

Another set of values is related to nontimber uses, some of which, such as recreation, have burgeoned over the past decade. Perceptions of the forest and forest activities by many individuals are like snapshots in time and space, and these limitations, without an understanding of the importance of scale and biological processes and change, often lead to mistaken and erroneous conclusions. Yet, it is these conclusions that give rise to concerns and issues that are driving political decision-making. Furthermore, because these perceptions are frequently placed in an outmoded historical context of what forests and forestry are all about, the conclusions are even more dangerous if used to form the basis of policies. Perhaps the most widespread example is that of clear-cutting: according to the 1989 Environics study, 71% of all persons sampled disapproved of this practice, yet from professional and scientific standpoints the perceived reasons for such disapproval are largely groundless.

If society's values have changed dramatically and many of its perceptions are ill-founded, there is an additional factor that is pervasive. The credibility of both governments and the forest industry sector have been eroded of late, which I would suggest has been exacerbated by well-meaning, expensive advertising campaigns by both parties. Indirectly and directly, the changing values, perceptions, and lack of credibility about forests and forestry in a society that is predominantly urban-based pose major threats to the development of policies required to maintain, if not improve, the health of Canada's forest industry.

Commitments to land, growing stock, capital investment, and forest management are long term if they are to be effective. For such commitments to be made there must be a framework of *certainty* within which the active participants can function; without it the future of the social and economic contributions currently flowing are in jeopardy. It has been said that the rotation age for much of Canada's forests is about 17 elections. The framework of *certainty* required is a set of policies that will not change 17 times but instead will change only when the parties involved, who are responsible and accountable, feel changes are necessary for the betterment of the common good and to improve both the health of the forest and the benefits it sustains.

What then are the conditions or precursors that must be taken into account when formulating new policies and amending existing policies to provide this framework of *certainty*?

Tenure

Whether it be in ownership or in rights, tenure must be clear and unequivocal. Tenure in terms of forestlands and resources, especially when it includes requirements for use and management, involves obligations; these, in turn, demand accountability if those with the rights and obligations are to be assessed. It is this assessment of accountability that is unclear, particularly for other than timber values.

Land Zoning

Closely tied to tenure is the zoning of land for different uses and management. For both private and public lands, patterns of use will change with demand and the nature and intensity of management with technology and the marketplace for products. Thus, delineation for a particular use or uses either singly or in combination has to reflect a clear comprehension of goals and objectives attainable over time. These undoubtedly will change; therefore, a process whereby they can be periodically reviewed is essential. Those participants with greater and longer term vested interests obviously have more at stake in the process than others and this has to be recognized. Clearly, the degree to which areas of single, inviolate uses are established influences the flexibility society has in the long run to accommodate changing demands and uses.

Multiple Use Management

It follows that if single use land zoning is minimized on forestlands, many of the common nontimber uses and values can not only be met but also be enhanced by appropriate forest and habitat manipulation. The problem is that present policies and attitudes generally use the process of constraint and removal of land from management rather than encouragement and incentives to develop appropriate management practices for nontimber uses and values. Such practices need to be developed, but to a greater degree there has to be recognition by those ultimately responsible, i.e., the public landowners and the governments who represent them, that management of resources comes at a cost. That cost has to be borne by those who benefit. Historically, little or no value has been placed on nontimber resources and certainly not on their management. Policies dealing with this aspect are sorely needed. Catch phrases about "integrated resource management" will not suffice.

Sustained Yield and Sustainable Development

Sustaining resources, values, and benefits in the long run is what policies affecting Canada's forests are about. The time frames for different resources and values vary as do their management, and it is these differences that are often the cause of dispute. The management of old-growth forests has a different time horizon than that associated with the same species of forest products, but this does not mean that management of both cannot occur in the same forest. What it does mean is that the sustainable yields and, hence, social and economic benefits will be dependent on the relative proportion of such areas. These proportions will change over time, reflecting age-class distribution as much as anything else, and so will the sustainable yield of both forest products and old-growth forests.

The Marketplace

The sale of Canada's forest products in the world marketplace is the single most important contributor to this country's balance of trade and, hence, to our economic well-being. As such, it is, ultimately, the driving force behind the manner in which we can manage our forests. Domestic markets and management for nontimber uses and values are important and have to be addressed, but there should be no misunderstanding that they can replace the world marketplace and sustain the present level of economic and social benefits that we now enjoy. This is not understood by the public and it is in danger of being ignored by policymakers.

If these elements - tenure, land zoning, multiple use management, sustained yield and sustainable development, and the marketplace - are the precursors of policy development, what of the process ? This provides, in my opinion, the greatest challenge and opportunity.

The process must provide for involvement of those with legitimate interests and responsibilities at two levels at least. One is at the provincial level and the other at that of the forest being managed. I am not ignoring the national level, but that is not where ownership and management decision-making reside. The setting of attainable and quantifiable objectives over specified time horizons is only a first step; the second step is to assess whether or not the objectives have been achieved and if not, why not? The process must be iterative and responsive to the dynamics of the forest, society, the marketplace, and management practices and knowledge.

Responsibility demands accountability. For those directly involved at either level, this is mandatory. To the public at large, credibility can best be assured if they are provided with an informative, understandable, independent report or audit on performance and the state of the forest on a regular basis. This was the intent of Recommendation No. 13 of "A National Forest Sector Strategy for Canada."

If processes such as these can be developed and are acceptable, then policies will likely meet the tests of effectiveness outlined earlier. Current policy directions are unclear. A number of the forces influencing policy development can adversely affect the future of forestry in Canada and our ability to manage our forests and provide a competitive supply of timber in the long run. The outcome, in my opinion, is in doubt. It will take concerted efforts and leadership from all responsible elements of the forestry community, in the broadest sense, to ensure that Canada's forests become the acme of what sustainable development is all about.

Determining Canada's Forest Area and Wood Volume Balance, 1977-1986

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Abstract

A model is developed to integrate existing data on forest land and timber and to determine the balance in area and volume following the removal of timber and subsequent regeneration of the forest. A consolidated statement on Canada's forest resource for the period 1977-1986, based on preliminary estimates, shows that annual accruals to timber volume are about 363 million m^3 and annual withdrawals total about 294 million m^3. This results in an average annual increase in standing timber volume of about 69 million m^3, or 0.3%. In terms of land area, about 1.43 million ha were added annually to the stocked productive land base, whereas annual withdrawals comprised 1.91 million ha. As a result, about 474 000 ha of forest land go out of production annually because they are not satisfactorily restocked to commercial tree species. The productive forest land that is not satisfactorily restocked comprises about 7% of the land base for forestry. Since the establishment of federal/provincial forest resource agreements in 1981, about 242 000 ha of backlogged not satisfactorily restocked forest land has been reforested. Despite this cooperative effort, the model indicates that the backlog of not satisfactorily restocked forest land has continued to increase, and a major additional effort will be required if the backlog is to be eliminated by the year 2000.

The forestry data base needs to be improved and greater emphasis on coordinating efforts among agencies is required. Recommendations are presented that can enhance existing classifications and demonstrate the increased productivity resulting from forest management activities.

Résumé

L'auteur élabore un modèle pour intégrer les données existantes sur les terrains forestiers et les ressources forestières et pour faire le bilan des superficies et des volumes à la suite d'activités de coupe et de la régénération ultérieure de la forêt. Un relevé cumulatif des ressources forestières du Canada pour la période de 1977 à 1986 fondé sur des estimations préliminaires montre que l'accroissement annuel du volume de bois est d'environ 363 millions de m^3 et les prélèvements annuels d'environ 294 millions de m^3, d'où une augmentation moyenne annuelle du volume de bois sur pied d'environ 69 millions de m^3, soit 0,3 %. En terme de superficie, près de 1,43 million d'hectares se sont ajoutés chaque année aux terrains productifs boisés, tandis que les prélèvements annuels totalisaient 1,91 million d'hectares. Par conséquent, environ 474 milliers d'hectares de terrains forestiers deviennent improductifs chaque année puisqu'ils ne réussissent pas à se régénérer de façon satisfaisante et à supporter des essences commerciales. Les terrains forestiers productifs insuffisamment régénérés constituent près de 7 % des terres réservées aux forêts. Depuis la création des ententes fédérales-provinciales sur les ressources forestières en 1981, près de 242 milliers d'hectares de terrains non régénérés après la coupe ont été reboisés. Malgré ces efforts, le modèle révèle que les terrains insuffisamment régénérés après la coupe ont continué d'augmenter et qu'il faudra déployer des efforts additionnels pour éliminer ces arrérages d'ici l'an 2000.

Il faudra apporter des améliorations à la base de données forestières et mettre davantage l'accent sur la coordination des efforts entre les organismes. L'auteur présente des recommandations qui peuvent améliorer les classifications existantes et montre l'accroissement de productivité découlant des activités d'aménagement forestier.

Introduction

Canada's forest resource has been the object of political praise for generations. For more than two centuries, its size and wealth of timber have been the source of the country's economic well-being. The magnitude of the timber resource lulled Canadians into complacency regarding maintenance and care of the forest, but no more.

Canadians have finally become aware of their forest resource. It is a topic of general conversation, letters to editors, emotional media coverage, and protests on the steps of provincial legislatures. It is single use versus multiple use. It is preservation versus share-the-forest. Dramatic evidence of this newfound public concern for forests and forest management is provided by the famous controversies surrounding South Moresby Island, Carmanah Valley, Temagami, and the Stein.

Recognizing the importance of the forest to the economy of Canada, one would assume that forestry data would be comprehensive. Because the forest is easily identified, lends itself to modern mapping methods, and can be easily measured and quantified, such a view by citizens of this country is understandable. After all, the forests of Canada grow largely on Crown lands (>90%); inventorying and managing the forest resource are the responsibility of the government; and the tax dollars used to support provincial and federal forestry organizations must be resulting in accurate and detailed information on our forest and timber resources. Unfortunately, such is not the case. Canada's forest statistics are inadequate.

Underfunded and with little or no interest from a smug urban public, government forestry agencies have been forced to manage an expanding resource sector with diminishing support. Maintaining a forest inventory and data on the rate of change of the resource has received low priority.

The need for data and information is critical, however. As the Auditor General (1988) noted in his report to Parliament

> "... given the importance of our forests to all Canadians ... the Government should also ensure that timely and accurate information on Canada's total forest resource is readily available."

This report briefly describes how current area and timber volume statistics were utilized to provide estimates of the average annual balance (increase or decrease) in land area and merchantable volume that occurred during the period 1977-1986. It emphasizes the weakness of the forestry data base and the need for better statistics to support forest inventory, and to track forest renewal and depletion events. Recommendations to improve the data base are presented.

Forestry Is a Business

With a land base that is greater than 90% under the jurisdiction of the provincial or federal Crown, forestry must be considered as the people's business. Billions of dollars are derived from the forest to support Canada's social programs, and millions of tax dollars are devoted to administering, protecting, planning for, and regenerating the resource. It is a very big business and if a business is to survive, management of capital and the interest that accrues to that capital must, in the long term, balance with the planned and unplanned withdrawal of capital.

Whether the forestry business involves recreation, wildlife, tourism, or timber, it must take into consideration the availability of capital. On the supply side, we are speaking of capital in terms of forest land area and timber volume, accruals to capital resulting from natural regeneration, planted stands, forest growth, and silvicultural practices; withdrawal of capital from planned harvests and unplanned events, such as fire and pest attack.

The report on Canada's forest area and volume balance by Honer and Bickerstaff (1985) was the first serious attempt to describe Canada's timber resource as of 1981 and the change in that resource for the 5 year period 1977-1981. It was a first approximation, an attempt to present complex data in a form that could be understood by foresters, businessmen, and laymen alike. It presented consolidated statements of capital and annual change backed by a series of 29 detailed tables.

The present paper summarizes Canada's land and timber capital for the years 1976 and 1986 and itemizes and reconciles the changes that took place during the intervening 10 year period. These estimates reflect several major conceptual and practical improvements to the basic growth-and-drain model employed, including a new procedure for estimating rates of growth directly from Canada's forest inventory. The earlier national presentation format is, in general, retained.

Data

Forestry data were provided by those provincial and federal government agencies responsible for managing the forest resource. Where figures were missing, as was common, best estimates were derived so that a more complete description of the resource could be presented.

Forest Capital

There are two kinds of forest capital. First, there is the land base available for timber production. This is considered to be a relatively fixed asset. Second, there is the growing stock, i.e., the current inventory of merchantable timber. This is looked upon as operating capital. The Canadian Forest Resource Data System (CFRDS) contains Canada's forest inventory. From these data, estimates of forest capital, in terms of land and timber, for 1976 and 1986 were developed.

Accruals to Forest Capital

Silvicultural activities reported by Kuhnke (1989) provided provincial data on changes in area that took place during the 10 year period under investigation. Where additional estimates were required, a regression technique was used.

To estimate the growth of stocked forest stands, a new set of location-specific growth rates for Canada was developed directly from the inventory data resident within the CFRDS. The index of productivity employed was the mean annual increment to the average age of maturity, using yield and age data for mature stands only. This was a departure from earlier practice, which used estimates reported by Bickerstaff et al. (1981). The many advantages of this new approach are partly due to the fact that resulting estimates of mean annual increment are a property of the particular inventory from which they are derived. Estimates of natural regeneration rates on burned-over lands, harvested lands, land damaged by pests, and old not satisfactorily restocked lands that revert to a stocked condition were reported by Honer and Bickerstaff (1985).

Withdrawals of Forest Capital

Four major sources of data were used. Records of harvest production were available from Statistics Canada on a volume basis, and from Kuhnke (1989) on an area basis. The Petawawa National Forestry Institute provided annual statistics on forest fires (Brady 1979; Ramsey and Higgins 1981, 1982, 1986, 1990). Mortality data attributable to forest pests were collected and made available through the Forest Insect and Disease Survey, Forestry Canada.

Basic depletion data for fire and forest pests are currently reported only in terms of area or volume respectively. Ideally, both volume and area should be measured and recorded to maintain up-to-date inventories, but because of practical difficulties, available statistics report only volume or only area. To make these statistics approximately comparable, it was necessary to transform them to a common base; in this case, the stocked productive nonreserved forest land from which the current growing stock has been depleted.

Where only one of volume or area was reported, the missing statistic was approximated by using the appropriate average yield in cubic metres per hectare to compute a derived area or volume equivalent for the missing variable. Thus, for each province and territory, roughly comparable paired area-volume depletion statistics were computed.

Salvage

Most forestry agencies conduct salvage operations depending upon the severity and extent of damage to the forest. However, statistics on the volume of wood salvaged are not differentiated from statistics on wood harvested. No area figures are reported. The rates of salvage used were those provided by the provinces and territories and reported by Honer and Bickerstaff (1985).

Model

> "... simplify the presentation of information by reducing the use of jargon and complex explanations, making it understandable to those without detailed knowledge of forestry and government operations."
> (Auditor General 1988)

The method used to present the status of Canada's timber resource is a statement of account showing the forest capital as of 1986, accruals to capital from 1977 to 1986, withdrawals of capital from 1977 to 1986, and the balance (surplus or deficit) for the period. It is a statement that will be familiar to every Canadian who uses a bank savings or chequing account.

Forest capital is the land base and the timber growing on it. Accruals are equivalent to deposits to forest capital and the interest on capital that occurs from forest growth. Depletions are equivalent to withdrawals from the available capital. The accrual - depletion balance is the 10-year difference of accruals less withdrawals for the reporting period.

Equations 1 and 2 represent the basic components of the model.

Balance 1977-1986 = Accruals - Withdrawals (1)
Capital 1986 = Capital 1976 + Balance (2)

The model is deceptively simple in concept, but its application to the current data base is not a trivial task. It requires a thorough understanding of CFRDS, the principles of forest inventorying, regeneration techniques and stand tending, the salvage operation, and the rate of change that takes place in the natural forest.

As with any model, certain assumptions were necessary:

- The land base for forestry of 233.1 million ha, described in Canada's Forest Inventory 1986, was accepted as being the land area available for timber production in 1976 and 1986
- The numerous component inventories within CFRDS were updated or backdated (as appropriate) in the computer to correct for the different ages of the data in making our estimate of the 1976 volume on stocked nonreserved productive forest land
- Using data provided in Canada's Forest Inventory 1981 (Bonnor 1982), the total amount of nonstocked land as of January 1, 1977 was established as being 10.8 million ha
- Productive forest lands that have not regenerated to minimum acceptable stocking levels after 10 years are classified as "old nonstocked"

Results

Tables 1 and 2 show the status of Canada's forest capital in 1976 and 1986 and the changes that have occurred during the 10-year period. These results are based on preliminary estimates and are subject to further refinement as the investigation proceeds. Highlights are described below.

Volume Capital of Canada's Forests

- The volume of growing stock is about 25 billion m^3; mature timber comprises about 18 billion m^3 and immature and regenerated stands contain about 7 billion m^3

Table 1. Canada's volume of forest growing stock: consolidated statement of capital and periodic change, 1977-1986

Volume Status	1976 (million m^3)	1986 (million m^3)
Growing Stock:		
Regeneration	282	353
Immature	6 982	6 730
Mature +	16 673	17 547
Total	23 937	24 630

10 Year Changes to Growing Stock Volume	1977-1986 (million m^3)	
Accruals (i.e. Growth):		
Natural		3 504
Standing forest - natural & untreated	3 402	
Regeneration - natural	102	
Planned		130
Standing forest - manmade & treated	87	
Regeneration - artificial	42	
Total		3 634
Withdrawals:		
Natural		1 381
Fire	743	
Pests	638	
Planned		1 560
Harvest	1 560	
Land reclassification	-	
Total		2 941
Balance:		
Net increase (decrease) in growing stock volume		693

Table 2. Canada's area of productive nonreserved forest land: consolidated statement of capital and periodic change, 1977-1986

Area Status	1976 (million ha)		1986 (million ha)	
Productive Forest Land:				
Not stocked		10.8		15.5
Recent	4.5		4.7	
Old	6.3		10.8	
Stocked		222.3		217.6
Regeneration	29.0		28.2	
Immature	91.9		85.9	
Mature +	101.4		103.5	
Total		233.1		233.1

10 Year Changes to Stocked Land Area	1977-1986 (million ha)	
Accruals:		
Natural		12.0
Regeneration - natural	12.0	
Planned		2.3
Regeneration - artificial	2.3	
Total		14.3
Withdrawals:		
Natural		10.7
Fire	6.1	
Pests	4.6	
Planned		8.4
Harvest	8.4	
Land reclassification	-	
Total		19.1
Balance:		
Net increase (decrease) in stocked land area		(4.7)

- Annual accruals to the growing stock volume amount to about 363 million m^3; natural regeneration and artificial regeneration provide 14 million m^3 and the remaining 349 million m^3 comes from the annual growth of standing timber and silvicultural treatments
- Annual withdrawals from the growing stock amount to 294 million m^3; harvest volumes account for about 53%, fires destroy about 25%, and forest pests kill about 22%
- The 10 year periodic balance in the growing stock volume is a net increase of about 693 million m^3, representing an annual increase in the growing stock of 0.3%
- An annual volume increment of about 22 million m^3 is foregone on the productive land area not stocked

Land Capital of Canada's Forests

- The land base for forestry is about 233 million ha; about 93% is stocked to commercial tree species
- Forests of natural origin comprise 214 million ha and man-made forests are estimated at 4 million ha
- Old nonstocked land is estimated to be about 10.8 million ha, or about 5% of the land base
- New nonstocked land, resulting from planned harvests and unplanned fires and pest attacks during the period, is estimated at 4.7 million ha, or about 2% of the land base
- Annual accruals to stocked land are estimated at 1.4 million ha; natural regeneration accounts for about 84% and artificial regeneration contributes about 16%
- Annual withdrawals from stocked land are 1.9 million ha, wildfire and pests accounting for about 56% and planned harvesting operations accounting for about 44%; no data are available on forest land alienations
- The average balance in stocked forest land is a deficit; about 474 000 ha of productive forest land went out of production each year

To place this deficit balance in another perspective, it can be shown that for every 100 ha of stocked productive forest land that is either harvested, burned, or damaged by forest pests, 12 ha are restocked by planting, 63 ha regenerate naturally, and 25 ha go out of production.

Discussion and Recommendations

At the 1985 annual meeting of the Canadian Institute of Forestry, 11 recommendations to improve the forestry data base were set down (Honer 1986). These recommendations are still relevant and after 5 years it is appropriate to discuss them and note progress or the lack of it.

1. The data base for the physical supply of timber should be maintained, but those public and private lands that can be managed economically should form the basis for future reports on Canada's forest inventory.

Canada's forest inventory is published every 5 years. Developed in cooperation with the provinces, it reports the land areas, timber volumes, maturity classes, and per hectare yields for the major forest types within each province and for Canada as a whole.

The inventory data base resides within the CFRDS. Forest attributes used in provincial and territorial inventories are subject to common classification criteria as developed by the Canadian Forest Inventory Committee (Haddon 1988). Area, volume, and descriptive data are referenced for geographical location. The system provides data summaries by province, ownership, or selected groupings and can produce maps showing the distribution of the resource throughout the country, i.e., showing productive forests, timber volumes, age, composition classes, and not satisfactorily restocked lands. The data base has had major technical improvements implemented and a high degree of quality control has been exercised on existing data. Details have been published and are available from the Petawawa National Forestry Institute (Gray and Nietmann 1989). The technical report is a comprehensive and authoritative reference on Canada's existing forest inventory data base.

A disturbing aspect of the current assessment concerns continuing erosion of the stocked forest land base and the subsequent increase in not satisfactorily restocked lands at a rate of 474 000 ha annually. Changes in regulations in several provinces now make restocking the land mandatory within a specified period and federal-provincial agreements have also contributed to restocking of 242 000 ha of not satisfactorily restocked lands. However, a much greater effort is required if the backlog of not satisfactorily restocked forest land is to be eliminated by the year 2000.

All inventory data on forest capital reported here are in terms of the physical supply and not the economic supply, which depends upon tree size, quality, species mix, logging costs, and infrastructures providing transportation, processing, and forest maintenance facilities.

2. The forestry data base should be enhanced so that all forest stands are classified according to site, age, and density in addition to forest cover.

The Canadian Forest Inventory Committee has made considerable progress in having provincial inventories adhere to agreed-upon minimum classification standards. However, the current data base has about 11 million ha of productive nonreserved forest unclassified as to maturity and about 21 million ha classified as unproven stocking. This represents 14% of the land base for forestry about which we have almost no information. This is the result of a lack of funding for inventory surveys, and future federal-provincial agreements should focus on closing this information gap.

3. National estimates of forest capability should be established for those lands identified as being part of the economic timber supply.

The Petawawa National Forestry Institute is making good progress in this sector. A report, soon to be published, will describe the growth of natural forests within Canada's forest regions. However, all reports based on data resident within the CFRDS suffer from a lack of data on that part of the land base not classified according to composition, age, stocking, or productivity. Rectifying this situation must be established as a priority item.

4. Forestry Canada should take the lead in establishing and supporting forest growth cooperatives involving government, industry, and universities to develop common measurement standards and to encourage the maintenance and sharing of forest growth, yield, and productivity data.

Forestry Canada participates in several forest growth cooperatives or councils, two being located in Canada. Participation is at the regional or institute level.

The cooperatives and councils are organized for the purpose of sharing data on forest growth. Permanent sample plot header information is made available for cataloguing and distribution among participating agencies. Forestry Canada has contributed data to these groups; however, many older sample plots, established during the 1930s and late 1940s and remeasured periodically every 10 years, seem to have been terminated and the data lost as a result of personnel changes, reduced funding levels, and reassignment of program priorities.

In his report to Parliament, the Auditor General (1988) was also concerned about Canada's approach to forestry's long-term data records:

> "... although some forest research sites have been continuously monitored for more than 50 years, their full value is not assessed regularly, nor are they managed as an investment and treated accordingly."

Canada's first growth plot was established in 1918 at the Petawawa National Forestry Institute, Chalk River, Ontario. Since that time, there have been growth plots established from coast to coast; a conservative estimate put the number at more than 25 000, representing a diversity of forest types and growing sites. Millions of dollars have been invested in acquiring these data and what we need now is a much greater commitment to service, i.e., to organizing the data bases, to reviving these forest measurement data, and putting this investment to work in managing our forests and in tracking their development.

A survey of North American mensurationists conducted in the early 1960s (Honer and Sayn-Wittgenstein 1963) identified forest growth and yield as the most important problem in their field. Recently, Canada's Forest Research Advisory Committee also recognized growth and yield as a priority program, yet resources devoted to this sector are miniscule. It is estimated that federal researchers in forest productivity receive, on average, about $4800 per study to carry out their operational tasks of field research and assessment. If we are to make any gains in this most important area, priority programs must receive priority funding.

Whether it be research or operations, forestry is a business, and for a business to be successful, it requires leadership and commitment to service. Fashions in management come and go, but one thing remains constant: if you are going to manage a forest and if you wish to optimize or possibly maximize timber growth, you must have data on the rate of change, i.e., the rate of change in tree growth, stand growth, and forest growth over time.

Leadership is most aptly demonstrated by action.

5. Forestry Canada, in cooperation with provincial and industrial forestry agencies, should establish and maintain on a periodic basis a survey of regeneration on lands depleted by harvest, fire, and pests.

An increased effort is required to develop and document the annual rate of natural regeneration that occurs following harvesting, fires, and pest attacks. Now that the CFRDS contains location-specific volume and area data that permit a quantitative assessment of the land's productive capacity, the system's usefulness will be enhanced by having the rate of natural regeneration also determined on a location-specific basis. Research plots established to assess the rate of regeneration should be linked to biophysical descriptions of the land base to permit referencing in a data base system such as the CFRDS. There needs to be greater coordination of effort than now exists.

6. Action should be taken at provincial and federal levels to maintain the data base for forestry in a current state and to ensure that land alienations and withdrawals due to harvesting, fires, and pests be incorporated into the data base on a regular and continuing basis.

The national effort to maintain the forestry data base is fragmented and lacks coordination. Although the Canadian Forest Inventory Committee has done excellent work in standardizing and inputting data into the system, there has been almost no federal leadership to have the silvicultural data, fire data, or harvesting data input on a location-specific basis. Reporting continues to be by questionnaire, with little or no quality control being exercised. Higher priority with respect to this problem area is required.

The forestry data base lacks information on land alienations, i.e., productive forest land removed from forest production to serve other purposes, such as pipelines, reservoirs, highways, recreation lands, parks, and wilderness areas. It is difficult for foresters to practice stewardship when the land base is being continually eroded for other purposes.

A letter to the editor of Victoria, British Columbia's *Times Colonist* (Yates 1989) illustrates the situation. The Vancouver Island natural gas pipeline will run from Campbell River to Victoria, with a feeder line into Port Alberni. The total distance is 305 km and it will have a minimum width of about 15 m. This will result in the permanent loss of almost 500 ha of the most productive forest growing sites in North America. As the writer noted "Once it is gone, it's never coming back. How much more of our prime forested land base can we afford to lose in the name of progress...?"

Although 500 ha may seem to be a very small quantity when considered in relation to the overall land base, this continuing removal of small parcels of highly productive forest land has a cumulative effect that cannot be ignored. Managing for sustained yield and sustainable development will be increasingly difficult unless timely data on the land base and the consequences of proposed alienations are readily available.

There are some encouraging developments that must be noted. The Ontario Ministry of Natural Resources has initiated a project in the Kirkland Lake area to establish a computer data base system to allow easy access to resource information and allow the ministry to develop different management scenarios and to analyze impacts on wildlife habitats, timber supplies, forest access, and other resource values. It will also provide insight into the effects of land removal and the impact of hydro dams and pipeline construction (Northern Daily News 1990). As Forestry Canada is cooperating in this project, linking the data base to the CFRDS should be undertaken.

7. Provincial forest agencies should publish silvicultural statistics (plantings, seedings, survival rates, treatments, etc.) by administrative region or district as part of their annual report of forestry activities. The data should be incorporated into the forest inventory data base at least every 5 years for summation in the Canadian forestry inventory.

Most provinces now report silvicultural activities as part of their annual report and data are collated and reported nationally by Forestry Canada. However, georeferencing these data for entry into the CFRDS would greatly assist in keeping track of the new forest. Great opportunities exist for national coordination of effort in this sector.

8. The Canadian Standards Association Committee on Scaling Primary Forest Products should review with Statistics Canada procedures used to collect and report volume of wood harvested data with the aim of improving depletion estimates for roundwood. Problems associated with obtaining area statistics, i.e., volume of salvage, cull, and decay, must be investigated.

Statistics on the volume of harvest are suspect. Maintained by Statistics Canada and based on a sampling of sawmills and logging operations, they do not seem to fully account for the harvest on a yearly basis. Official scaling returns from some provinces are included in the totals, but other provincial data do not seem to enter into the annual statement.

The problem is compounded further when annual harvest volume data are examined in conjunction with annual figures on the area of harvest. In several provinces, the resulting yield per hectare seems to be unrealistic. Small differences between harvest yield and yield estimated from the mature standing forest are expected because the harvest volume is a net merchantable volume (decay and nonmerchantable material removed), whereas the yield estimate of the mature forest is generally a gross merchantable volume. In several instances, however, the harvest yield was more than two times the average yield of the mature standing forest. This suggests that there are discrepancies in the data and that a formal review of the overall process is required.

The Canadian Standards Association Committee on Scaling Primary Forest Products has made some initial inquiries regarding the processes used; however, these volunteers can only do so much. Forestry Canada should exercise its leadership role and have this situation rationalized. Perhaps it is time to reinstate the forest industry - government - Statistics Canada committee that was disbanded in the late 1970s and have the problem officially reviewed.

9. Fire statistics should include the merchantable volume of timber killed, not just the area burned, with annual provincial reporting at the regional or district level and totals for the province. Depletion estimates on economic forest lands should be identified and reported.

If a national data base on Canada's forest is to be established and maintained, burned areas must be georeferenced for entry into the system so that estimates of the wood volume destroyed by fire can be made. Current handling of fire statistics by questionnaire and summation by province is inadequate to assess the impact of fire on future timber supplies or other resource uses.

Forestry Canada should take the initiative to have fire statistics reviewed cooperatively with the Canadian Interagency Forest Fire Centre and the Canadian Committee on Forest Fire Management.

10. Studies on pest losses (decay, growth loss, mortality, etc.) should focus on developing a rational methodology that will permit their assessment, reporting, and integration into the forest inventory data base. This activity should be coordinated by Forestry Canada, but should also involve strong representation by mensurationists and forest inventory personnel from the provinces and industry.

Canada's mature and overmature forests comprise about 44% of the land base available for forestry. From this land base, about 1.9 million ha, or 0.8%, is withdrawn annually as a result of harvest, burns, and pest damage. Withdrawals due to pest caused mortality amount to about 0.2% of the land base. Overall volume losses attributable to decay and decreased growth caused by these pests are not explicitly considered in the results presented here, but they could conceivably exceed mortality figures by three times or more.

Forest pests are major contributors to the loss of productive timber. Overmature stands lack vigour, their defense mechanisms are weak, and their recovery from attack is slow. Being of fire origin, they await either harvesting or total destruction before rejuvenation occurs. Without good data and good information on pest losses, forest managers will always be in a reactive position - reacting to the forest pests that are destroying the forest and our economic base.

The health of Canada's forests is of primary importance to all forest managers. The data base program on pest damage initiated at the Petawawa National Forestry Institute must receive the support necessary to integrate it into the CFRDS.

11. Statistics on the man-made forest (Cayford and Bickerstaff 1968; Honer and Bickerstaff 1985) and the treated natural forest should be maintained. Large government investments are being made to renew and enhance the forest resource and a separate data base will permit measuring and evaluating the forests' response (survival, growth, yield) to these investments of tax dollars.

There has been no synthesis of data or information on Canada's man-made forest since the report of Cayford and Bickerstaff (1968). Its magnitude is now estimated to be 4 million ha. With appropriate silvicultural treatments, this forest is capable of utilizing the full potential of the growing site, producing yields that are greater than those of the natural forest.

A review of yield tables developed for planted white spruce (Berry 1987) and red pine (Berry 1984) (site index 24 at 50 years, total age 50 years from 2.0 m x 2.0 m planting) at the Petawawa National Forestry Institute shows mean annual increments of 8.06 $m^3 \bullet ha^{-1} \bullet year^{-1}$ and 9.92 $m^3 \bullet ha^{-1} \bullet year^{-1}$ respectively. These data suggest that the productivity of lands in the Ottawa valley could approach that of British Columbia's coastal rain forest, given proper establishment and protection.

To fully assess the situation requires appraising the man-made forest as a distinct population. Yield tables based on protected research plots provide estimates of potential productivity; however, sampling the population, planted and growing under operating conditions over a broad geographical range, is necessary to fully assess the increased yield from these silvicultural activities.

It is imperative that an assessment of the man-made forest and the managed natural forest be carried out on a periodic basis. By tracking yield and growth performance, it is possible to gain a better appreciation of the level of management necessary to maintain sustainable development of the forestry sector.

Conclusion

This study provides an approximation of changes occurring in the forest resource under present levels of management. The forestry data base needs to be improved and greater resources must be devoted to provincial and national programs if an accurate account of the resource and changes to it is to be maintained. With the federal mandate in statistics well established, Forestry Canada should take advantage of this opportunity to exercise real leadership. We need organization, coordination, and accountability in our approach to this problem.

We need new initiatives to replace old inertias.

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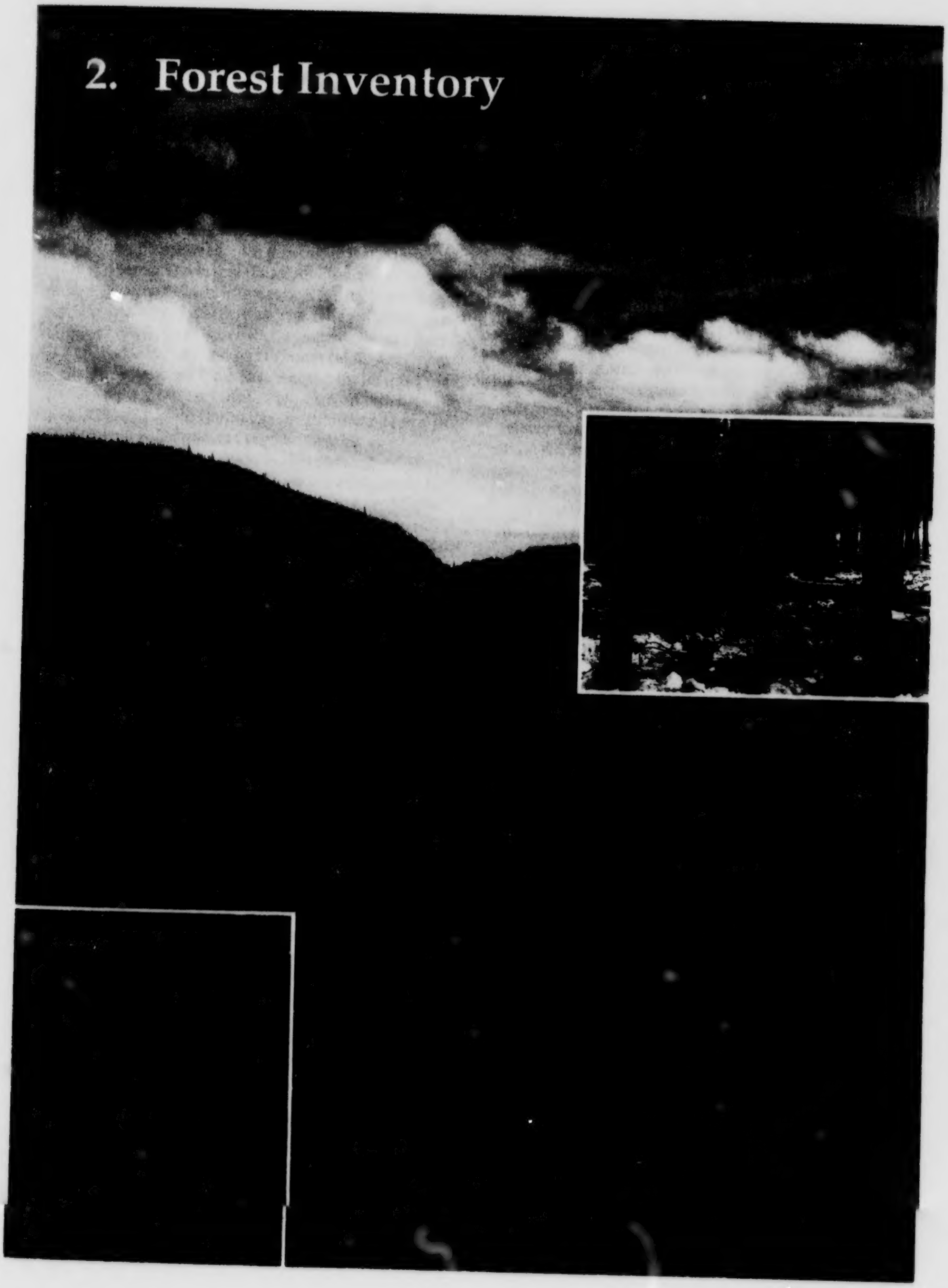
2. Forest Inventory



Canada's Forest Capital

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Abstract

Canada's forest inventory has been referred to as being the best in the world as well as being a national disgrace. About 30 years ago, only a timber inventory was required. Hence, the original national inventory system was designed to deliver information for timber management. Since the mid-1970s, due to public pressure, timber managers have had to include considerations for other resource values and environmental sensitivity in the planning process. This has resulted in the need for information not only on timber but also on other resources as well, including the constraints under which a particular timber management regime may be implemented. The acquisition of this new information need, however, has not been addressed adequately in the budgets of most provinces or in the national forest inventory program. This paper examines the provincial and national inventory programs in terms of their strengths and weaknesses, and develops a strategy for corrective action.

Résumé

L'Inventaire des forêts du Canada a été qualifié soit de meilleur au monde, soit de honte nationale. Il y a une trentaine d'années, nous n'avions besoin que d'un inventaire des ressources forestières. C'est pourquoi le système original d'inventaire a été conçu pour compiler des données sur l'aménagement forestier. Depuis le milieu des années 70, en raison des pressions exercées par le public, les aménagistes ont dû incorporer au processus de planification des données sur les valeurs d'autres ressources et sur la vulnérabilité de l'environnement. Il s'ensuivit un besoin d'information non seulement sur les ressources forestières, mais également sur d'autres ressources, y compris les contraintes à la mise en œuvre d'un régime donné d'aménagement forestier. Les budgets de la plupart des provinces et le programme national d'inventaire des forêts n'ont toutefois pas tenu suffisamment compte de ce nouveau besoin d'information. Le présent article examine les points forts et les points faibles des programmes d'inventaire provinciaux et national et élabore une stratégie sur les mesures à prendre pour les améliorer.

Introduction

Forestry in Canada has been largely timber oriented. Silviculture and harvesting have dominated the attention of both academia and administration, and this has been reflected in provincial and federal budgets. Senior administrators in government and industry have traditionally placed high priority on growing trees and on making a profit. Environmentalists have effectively challenged this status quo and emphasis has shifted to values other than timber. Public pressure, combined with campaigns by special interest groups, has had a major influence on the focus of forestry. Traditional timber-growing and harvesting stereotype foresters often refer to this influence as negative. The public, in general, tends to side with the environmentalists, voicing strong opinions when damage is inflicted on the environment, such as clear-cutting in a scenic watershed or on an environmentally sensitive site. The news media has often focused on sensationalism, and also tends to side with the environmental movement. With all of these varied interests in forest management practices, the information that we need to obtain about the forest resource can no longer be limited mainly to timber, as has been the case in the national inventory program.

Information on the forest resource is adequate for national planning if one is satisfied with averages. However, when dealing with local areas, such as a watershed, the sampling system may not have been designed to deliver information on a site-specific basis. Nevertheless, generalized inventory data are often used to provide information on individual stands, and when such misapplications deliver information that has a high variance, confidence in the inventory generally takes a dive. The focus of this paper is on the quality of information that is available on Canada's forest capital. Recommendations, including budget allocation, are presented for upgrading the national inventory program to the desired level.

Canada's Forest Inventory

The latest official forest inventory statistics were published in 1989 based on information updated to 1986 (Forestry Canada 1989). Key findings of the Forestry Canada report are presented in Table 1.

The data in Table 1 represent information on inventoried forestland. Approximately 10% of the forestland has not been covered adequately with inventory.

Of the 243.7 million ha of productive forestland, 4.3 million ha are estimated to be not stocked, and on 21.4 million ha, the forest inventory has not confirmed that stocking is at an acceptable level.

Table 1. Forest inventory statistics

Province/Territory	Forestland (million ha	Productive Forestland (million ha)	Volume (million m^3)
Newfoundland	22.5	11.2	530
Prince Edward Island	0.3	0.3	26
Nova Scotia	4.0	3.8	244
New Brunswick	6.3	6.1	571
Quebec	94.0	54.8	4 250
Ontario	80.7	38.3	3 695
Manitoba	34.9	14.9	736
Saskatchewan	23.7	15.9	964
Alberta	37.7	25.4	2 952
British Columbia	60.3	51.1	9 021
Yukon Territory	27.4	7.6	486
Northwest Territories	61.5	14.3	446
Canada	**453.3**	**243.7**	**23 921**

The Forestry Canada (1989) report contains detailed statistics about the timber inventory by province and territory. However, it lacks some important information that is essential for modern resource management. Essential information excluded from the report includes growth, depletion, and mortality data. Another important component of the forest inventory data base is land used allocation. However, because of the absence of a compatible provincial and national land use policy, which could be accepted by both timber growers and environmentalists, statistics on Canada's timber resource will vary. Alienation of forestlands from forest production can reduce current and future timber supplies at a higher rate than harvesting or even an inadequate reforestation program.

Provincial forest inventory statistics are generally more detailed than the national summary data. Several of the provincial inventory programs maintain information on a stand-specific basis. The reliability of this information varies depending on the quality of airphoto interpretation, the intensity of sampling and quality control, and on the techniques used to derive stand-specific descriptive statistics from the sample data base.

Most provinces have introduced geographic information systems (GIS) into their inventory programs. The national forest inventory also utilizes GIS for data management and applications. In this respect, Canada's inventory program is in an excellent strategic position to be enhanced and upgraded to the desired level.

Information Needs

The traditional timber inventory program in Canada urgently requires major upgrading. The following is a summary of the major considerations that need to be included in the development of the enhanced national inventory program.

Topographic and Cadastral Information

Primary to all strategic data needs are accurate and standardized topographic and land ownership information. Such information is required to georeference the resource from an individual stand basis to a national survey level. Given an accurate GIS base, the various levels of thematic resource information can be integrated. As well, their interrelationships can be evaluated. Analysis of investment opportunities, wood supply distributions, forest management options, and alternate land uses requires information that can be obtained from digitized base and cadastral maps, combined with digital elevation models. This has a cost associated with it of $0.50-1.00 per hectare depending on the area.

Resource Inventories

Resource inventories need to be area specific and described in terms of continuous variables, not as averages. A generalized resource inventory information system that can satisfy current information needs is illustrated in Figure 1.

The main components of an inventory system are

- classification
- multiphase sampling
- resource inventory/information statistics
- updated resource inventory/information

There are established processes involved in each component. The classification of land is important for land use allocation, as well as for inventory purposes. It

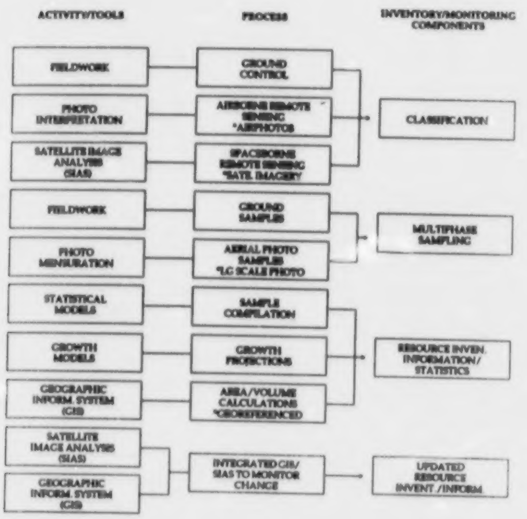
ACTIVITY/TOOLS
PROCESS
INVENTORY/MONITORING COMPONENTS
FIELDWORK
GROUND CONTROL
PHOTO INTERPRETATION
AIRBORNE REMOTE SENSING *AIRPHOTOS
SATELLITE IMAGE ANALYSIS (SIAS)
SPACEBORNE REMOTE SENSING *SATE. IMAGERY
CLASSIFICATION
FIELDWORK
GROUND SAMPLES
PHOTO MENSURATION
AERIAL PHOTO SAMPLES *LG SCALE PHOTO
MULTIPHASE SAMPLING
STATISTICAL MODELS
SAMPLE COMPILATION
GROWTH MODELS
GROWTH PROJECTIONS
GEOGRAPHIC INFORM. SYSTEM (GIS)
AREA/VOLUME CALCULATIONS *GEOREFERENCED
RESOURCE INVEN. INFORMATION/ STATISTICS
SATELLITE IMAGE ANALYSIS (SIAS)
GEOGRAPHIC INFORM. SYSTEM (GIS)
INTEGRATED GIS/ SIAS TO MONITOR CHANGE
UPDATED RESOURCE INVENT./INFORM.

Figure 1. Generalized resource inventory information system.

is generally based on ground control, conventional aerial photographs, and satellite imagery. The tools used for classification consist mainly of fieldwork, photo interpretation, and satellite image analysis. Multiphase sampling is also a major component of inventories because it provides the required statistics for each category identified during classification. Ground and airphoto sampling are usually the two major processes, involving both fieldwork and photo mensuration. A third major component of resource inventories is derived from the classification and sampling, and also constitutes the major deliverables, i.e., the resource inventory information and statistics. The processes involved include sample compilation, growth projection, and georeferenced area-volume calculations for each category defined in the classification component. To calculate the area of individual types or polygons and to georeference them, a geographic information system is often used because of its flexibility and cost effectiveness. However, it must be emphasized that such a system is only a tool in the total process. In most cases, as soon as an inventory is compiled, it is out of date due to the continuous disturbances that are occurring in any given area. Some of these disturbances are due to natural causes, such as fire, insect damage, etc., others are caused by humans, e.g., harvesting, reforestation, etc. Therefore, the resource inventory information needs to be updated. The process involved here is change detection, where both GIS and satellite imagery are cost-effective tools.

Technological Challenges

Traditionally, large field parties have been used to survey the land. Timber cruising, geological surveys, and resource inventories had many common elements prior to the introduction of remote sensing techniques. Medium- and small-scale aerial photographs have provided opportunities to examine large areas in terms of such things as timber types, landforms, geological formations, and agricultural uses. Extensive ground surveys have changed gradually to multiphase and multistage sampling designs for both efficiency and quality control. As the resolution of airborne remote sensing products has improved, even more fieldwork has been substituted with large-scale aerial photographs and photo sampling has become a new challenge to statisticians. Information that could only be obtained in the past from ground surveys can now be closely approximated through a combination of extensive photo and limited ground sampling, used within the context of double sampling or even higher order multiphase sampling designs. This is possible by correcting or "ground truthing" estimates from photographs with sample measurements made on the ground.

Satellite imagery, such as the early versions of Landsat multispectral scanner data, has become fairly popular in a relatively short period of time, mainly because large areas can be covered frequently at a lower cost than through the use of conventional photographs. However, the low resolution of Landsat imagery has reduced its use mainly to monitoring changes, except in research and development environments, where claims have been made beyond its operational capabilities. With the advent of Thematic Mapper products, both spatial and spectral resolution have improved considerably, and the operational usefulness of spaceborne scanner products has increased. In addition, the release of SPOT data has shown resolution capabilities that can match conventional aerial photographs in many areas.

The major technological challenge of the 1990s, however, will be the replacement of conventional aerial photographs with high resolution airborne scanner data, such as MEIS. When analyzed and colour enhanced, MEIS products can appear as if they were large-scale aerial photographs, but their main advantage is being in digital form. Once a library of spectral signatures can be compiled for such applications as forestry, agriculture, geology, land use, land production capability, and environmental sensitivity, high resolution airborne scanner imagery will challenge airphoto interpretation in a manner similar to the replacement of manual drafting by GIS.

In the past, the development of remote sensing technology has occurred as a joint effort between researchers and resource managers. This development has not progressed as fast as it could have, mainly because both the users and those who have had major control of funding the new technology have learned their resource management skills in a more conventional and manual data acquisition environment. Hence, remote sensing techniques, especially those involving satellites, have been met with some scepticism and even resistance.

However, with increasing public concerns about the environment and changes that are being inflicted upon the land base, resource managers will be subject to scrutiny at a scale previously unimagined. Rightly or wrongly, practices previously considered acceptable and even cost effective will be challenged by individuals or groups that will likely have up-to-date information about the land base through remote sensing technology combined with powerful geographic information systems. In addition, in many cases the resource managers' own data will be used as the base over which space and airborne scanner data will be displayed, showing the adverse effects on the environment. It will no longer take 2 years to compile such an inventory, it will be more like 2 days.

Entrepreneurs working with land information systems are just a few steps away from setting up data marts where information, on floppy disks, may be purchased about most parts of the world. There will be land information distributors, wholesalers, and retailers. Conflicts over land use and resource management practices, whether involving forestry, mining, agriculture, or a range of sectors, will be dealt with in the 1990s from a new power base: current information, which can be manipulated with ease to highlight areas of concern. This will include information about all resources, not just timber.

Availability of information about the natural resources of a region, province, or country creates further problems or challenges. Surveillance of natural resources by competitors could become an active industry, creating both marketing and legal problems. A comment to the traditional timber-focused foresters: the public will be watching, and they will have the tools to get current information. What would it cost to reinventory Canada's productive forestland using new technology? About $1 per hectare or $244 million over 10 years or $24.4 million per year. This is just for reinventorying and does not include maintenance, updating, growth projections, and distribution of data. So let's stop talking about the national disgrace, poor inventory, etc. Instead, let's dedicate the resources required to provide the information that is needed.

Conclusions

Public pressure on resource managers to justify their decisions on land use and environmental issues will result in increased applications of remote sensing and GIS technologies. Demands for land-related information will increase and the data distribution industry will expand. A more informed public and, in particular, special interest groups will help to resolve some of the existing land use conflicts. At the same time, readily available data can become powerful weapons against decisions that are contrary to public interest.

Conventional aerial photographic products will be replaced by airborne multispectral scanner data in resource management, while the use of satellite imagery will expand to include global environmental monitoring. Remote sensing technology will become the principal tool for data acquisition. Geographic information systems, on the other hand, will be used for the management and distribution of georeferenced land information.

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Canada's Forest Inventory: The Sustainable Commercial Timber Base and its Growth Rate

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Abstract

The national forestry inventory (Canada's Forest Inventory) is described as a component of the Canadian Forest Resource Data System (CFRDS). The inventory is used to estimate that portion of the forest available for sustainable commercial timber management (the "current woodshed") and the timber growth rate of that area (productivity). The analysis uses detailed CFRDS data and also regional auxiliary information in the CFRDS based on surveys and expert opinion. One personal guess concerning economic accessibility is added due to a lack of expert opinion - readers are invited to substitute their own factor. The current woodshed is estimated to be about 100 million ha, which is 41% of the productive forest area or 10% of the whole country. The timber growth rate is estimated to be 172 million m^3/year (68% coniferous, 32% broad-leaved). More detailed studies should eventually refine these estimates, but they serve as a first approximation.

Résumé

L'inventaire forestier national, c'est-à-dire l'Inventaire des forêts du Canada, est décrit comme une composante du Système de données sur les ressources forestières canadiennes (SDRFC). L'Inventaire sert à estimer la portion de la forêt se prêtant à un aménagement forestier commerciale durable (les «actuelles réserves de bois») et le taux de croissance de ces superficies (productivité). L'analyse a recours à des données détaillées du SDRFC ainsi qu'à des données régionales complémentaires fondées sur des relevés et des opinions d'experts qui figurent dans le SDRFC. Faute d'opinion d'expert à l'égard de l'accessibilité économique, les lecteurs sont invités à utiliser le facteur qu'il jugent adéquat. L'estimation des réserves actuelles de bois sur pied atteint près de 100 millions d'hectares, ce qui représente 41 % des terrains forestiers productifs, ou 10 % de l'ensemble du pays. La croissance est estimée à 172 millions de mètres cubes par année (68 % de résineux, 32 % de feuillus). Des études plus détaillées finiront par permettre d'améliorer ces estimations qui sont pour l'instant approximatives.

Introduction

This paper briefly describes the national data base known as Canada's Forest Inventory (CanFI). The inventory is "discounted," or "netted down," to answer two key questions:

1. Which part of the forest is available for sustainable commercial timber management?
2. What is the timber growth rate on that area?

Canadian Forest Resource Data System (CFRDS)

The CFRDS consists of several spatially referenced data bases that describe various aspects of the country's forest resources. Most data in the CFRDS come by aggregation from more detailed provincial and territorial surveys. The CFRDS uses a geographic information system (GIS) to store attributes that may be descriptive (e.g., forest type) or quantitative (e.g., wood volume). The attributes are related to map polygons. The most detailed spatial resolution is the CFRDS cell, which ideally is 100 km^2 and in CanFI practice corresponds to the provincial inventory map sheet. Other information may be related to larger map polygons, such as administrative or biological regions.

Data bases can be handled alone or in combination. A full description of the CFRDS and its potential is not appropriate for this paper. Briefly, however, the CFRDS contains:

- Canada's Forest Inventory
- Canada's Biomass Inventory (Bonnor 1985)
- other auxiliary information, such as pollution deposition

The CFRDS is maintained by Forestry Canada at the Petawawa National Forestry Institute. Requests for information, or suggestions for cooperative studies, are welcome.

Spatial and attribute resolution of the CFRDS is designed for national level overviews, not for local purposes, such as forest management. There are about 43 000 cells in the forest and biomass inventories. This is appropriate for mapping at scales of about 1:20 million, and allows the data to be regrouped into fairly large regions, such as Rowe's forest regions and sections (Rowe 1972).

Canada's Forest Inventory

CanFI is mostly produced by aggregation from source inventories, such as provincial forest management inventories. The current version was collected in 1986. It will be refreshed in 1991 using source inventories that have been replaced or completely updated since 1986.

The current inventory is described in two reports - "Canada's Forest Inventory 1986" (Forestry Canada 1988) and a technical supplement to that report (Gray and Nietmann 1989).

We are proud of CanFI, but not complacent. Experience has shown that the resolution is about right, and more detailed questions are referred to the provinces.

Gaps in the inventory data are being filled steadily. Techniques have been developed to minimize the effect of incomplete data or missing values. Source inventories improve steadily; for example, forest age is still not available everywhere, but is becoming universal in new inventories. The 1991 inventory will have estimates for all significant geographic areas of forest in the country.

In 1986, the average information in CanFI was 10 years old. Some critics have expressed concern that the inventory is not "current." Stand level inventories upon which we draw information are steadily becoming more current, but remote areas of low commercial interest do not justify frequent reinventorying. For national aggregations, the age of inventory information is less critical than it would be for individual stand management.

Productivity of the forest had been a major omission from the CFRDS, but this has now been corrected with comprehensive mean annual increment (MAI) figures. These have recently been calculated within CanFI as MAI = mature volume/mature age (S.L. Gray, unpublished data).

Coniferous and broad-leaved MAIs are each reported in gross merchantable cubic metres per hectare per year. Productivity is stratified by province and forest section. Site class and predominant genus are also used to stratify where source data allow. This paper is one of the first to use the new productivity information.

Although each successive national inventory is the best available estimate of the forest, differences between inventories cannot be used to calculate net change because the inventories are not a true time series, and real change is masked by procedural change and the variable ages of source data. It should be possible to sample, within the framework of the CFRDS, to monitor change in the most significant statistics, such as the amounts of forestland, productive forest, and stocked productive forest.

In this environmentally sensitive age, it should be pointed out that the CFRDS covers all of Canada's forest resource, not just the timber base. Because timber management has led the way, and has paid for most of the comprehensive surveys, timber information tends to be better represented in forest inventories than the other components of forest management.

The "Woodshed" and Its Productivity

The inventory can be used to answer the two questions posed in the introduction to this paper.

1. Which part of the forest is available for sustainable commercial timber management?
2. What is the timber growth rate on that area?

This analysis involves three sources of information:

1. "CFRDS" - regular components of CanFI (draft information, as in Tables 1 and 2).
2. "CFRDS Aux." - auxiliary information linked to CanFI from the best available sources, be they surveys or expert opinions.
3. "Guess" - a purely personal guess concerning economic accessibility pending a more detailed national economic wood supply study. If the reader can think of a better number, then adjust accordingly.

In this exercise, we start with the total forest estate and net down step by step to estimate the current woodshed. The current woodshed is that part of the forest that is sufficiently productive, and currently available and accessible, for sustainable timber management.

The estimates will be of the total area, volume, and growth of the woodshed. The CFRDS could also be used to investigate the woodshed's distribution (using maps) and structure (ownership, forest type, age, etc.). It cannot immediately estimate change to the woodshed except through accounting exercises.

Netting Down to the Current Woodshed

The CFRDS indicates that within Canada's 997 million ha, there are 453 million ha of forest.

Not all of the forest is on sites productive enough to grow stands with merchantable volumes of possible commercial interest. In timber terms, there are 244 million ha of productive forest.

CanFI recognizes major legal reservations from timber harvesting, such as national parks. There are 233 million ha of productive forest that are not reserved (Table 3). This is 23% of Canada or 51% of the forest.

The 1984 biomass inventory in the CFRDS contained "access" as a cell level attribute. The presence of an access route (road, rail, water) in one of the 43 000 cells flagged all data in that cell as being "accessed." This information has been transferred from the CFRDS to CanFI, and can be used as draft information pending the updated 1991 inventory.

Recent analysis of the CFRDS reveals 136 million ha of accessed productive forest that are not reserved.

Table 1. Netting down - The current woodshed

		Source
• Not reserved	233 million ha	Table 3
• Not accessed		
• Accessed	136 million ha	CFRDS draft
• Growing stock[a]		CFRDS
Coniferous	99 m^3/ha	
Broad-leaved	33 m^3/ha	
All species	132 m^3/ha	
• Policy constraint	18%	CFRDS Aux.
• Economically inaccessible	10%	Guess
• Current woodshed	100 million ha	

[a] Volumes in gross merchantable pulp.

Table 2. Productivity of the current woodshed

				Source
• Current woodshed, approximately 100 million ha				Table 1
(41% of productive forest, 10% of Canada)				
• Currently nonstocked		7%		CFRDS Aux.
• Stocked woodshed		93 million ha		
• Productivity (MAI)[a]				CFRDS draft
Coniferous	1.25	117	68	
Broad-leaved	0.59	55	32	
All species	1.84 $m^3 \cdot ha^{-1} \cdot year^{-1}$	172 million m^3/year	100%	

[a] Volumes in gross merchantable pulp.

Table 3. Netting down - Productive forest not reserved

		Source
• Canada	997 million ha	CFRDS
• Other lands		
• Forest	453 million ha	CFRDS
• Unproductive		
• Productive	244 million ha	CFRDS
• Reserved		
• Not reserved	233 million ha	CFRDS

Standing volumes on this forest average 132 gross merchantable m^3/ha (99 coniferous + 33 broad-leaved m^3/ha).

To this point, regular CFRDS information has been used. Now we begin using auxiliary information to estimate economic accessibility and policy constraint. This information is as good as the surveys and expert opinions offered; it is the best available. These factors are quite variable, so the "woodshed" is a moving target and is dependent on such things as road development, mill location, and market conditions, as well as land use policies and practices.

Reserved lands are not the only areas with limitations on timber harvesting. A significant portion of the "not reserved" forest is constrained from timber harvesting for many reasons (e.g., shoreline and other protective reservations, owner attitude). Auxiliary information provided to the CFRDS by the provinces and territories indicates a further [illegible]8% net down for policy constraint (K. Power, unpublished data).

"Access" in the CFRDS defines the major access route network of the country, but this is not the same as economic accessibility. Within the accessed cells, there is obviously some forest that is not economically accessible. On the other hand, there is also a "halo" of forest beyond the road/rail/water network that would be economically accessible. Economic accessibility is a complex attribute that has not yet been estimated for the whole country by national economic wood supply experts. For the sake of this discussion, a personal guess is volunteered that the net adjustment for economic accessibility is minus 10%.

The bottom line of these calculations is to estimate the current woodshed at about 100 million ha (Table 1). This is 10% of Canada, or 41% of the productive forest area.

Productivity of the Current Woodshed

Recent auxiliary information provided by the provinces and territories has allowed Forestry Canada to estimate (K. Power, unpublished data) that about 7% of the productive forest is not stocked. If adjustment is made to the current woodshed for areas that are temporarily fallow in timber production terms, then the stocked portion is 93 million ha.

New CFRDS productivity data provide growth rates to maturity as indicated by the existing mature forest. Better management could obviously improve this performance, but it is a good conservative base to work from.

The average MAI is as follows: coniferous, 1.25 $m^3 \bullet ha^{-1} \bullet year^{-1}$; broad-leaved, 0.59 $m^3 \bullet ha^{-1} \bullet year^{-1}$; and all species, 1.84 $m^3 \bullet ha^{-1} \bullet year^{-1}$.

When this is applied to the 93 million ha of stocked current woodshed, the absolute productivity becomes coniferous, 117 million m^3/ha; broad-leaved, 55 million m^3/ha; and all species, 172 million [m^3/a] (Table 2).

This approximation obviously merits considerable refinement, with more detailed studies and with the cooperation of wood supply experts. As a first approximation, however, it should be reasonably close. CFRDS/CanFI is available for more refined calculations and to examine the structure of the "woodshed." Ownership, location, forest type, age, volume, and species mix will all be significant in those detailed studies.

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Alberta's Forest Inventories - Responsive to Change

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Abstract

Inventories in Alberta are driven by information and management needs. An historical perspective outlines the evolution of inventory purposes and the resulting specifications that have been used in provincial-scale inventories. Challenges faced in using the current Phase 3 Inventory are described. The subsequent Cooperative Vegetation Inventory provides an integrated approach to resource inventories and has been adopted by both government and forest management agreement holders in the province. The success of this cooperative effort will result in a compatible digital map and attribute data base for a majority of the forested land base in a fraction of the time it would take any one agency to complete.

Résumé

Les besoins en matière de données et d'aménagement motivent la tenue d'inventaires en Alberta. L'auteur, dans une perspective historique, trace l'évolution des raisons qui ont motivé les inventaires et présente les exigences qui ont présidé à la tenue des inventaires provinciaux. Il décrit les enjeux de l'actuelle phase 3 de l'inventaire. L'inventaire conjoint subséquent de la végétation offre une approche intégrée à l'inventaire des ressources et il a été adopté à la fois par le gouvernement et par les détenteurs au titre des ententes d'aménagement forestier de la province. Le succès de cet effort de coopération permettra d'obtenir une carte numérique compatible et une base de données attributives pour une vaste majorité des terrains boisés beaucoup plus rapidement qu'il n'en aurait fallu à un organisme quelconque.

Introduction

The Alberta Department of Forestry, Lands and Wildlife is responsible for the inventorying and managing public land and renewable resources in the province. This large department is comprised of three divisions, namely Alberta Forest Service, Fish and Wildlife, and Public Lands.

For resource purposes, Alberta is divided into two administrative areas. The White Area is the agricultural land base and is managed by the Public Lands Division. The Green Area is the forested part of the province and is managed by the Alberta Forest Service. The Green Area makes up approximately 60% of the province and is subdivided into regions called forests. Each forest is divided into forest management units that are managed as sustained yield units (Anon. 1986a). The following discussion on forest inventories will focus on the Green Area.

The present need to gather inventory information is being driven by a number of factors. The ability to practice integrated resource management is dependent on a solid integrated inventory. Sustained yield, resource allocation, and land use planning are all impossible without an accurate, up-to-date inventory. The public also has a strong interest in resource allocation or utilization and other environmental concerns. Now more than ever, we must convince the public that we have a solid understanding of what is out there and how best to manage it. The trend in inventories has moved away from well-defined, single-sector inventories towards more integrated and ecological approaches. These are less defined from the point of view of a single resource, but they provide for a wider degree of uses. Alberta is responding by combining as many agencies as possible in the inventory process and by describing the resource itself rather than its uses.

Historical Perspective

To provide some background on the Alberta situation, a brief historical summary of Alberta's forest inventories is presented. Inventories in Alberta have always been driven by specific needs. The need to obtain baseline information on the distribution of forest types was the impetus to launch the first provincial-scale forest inventory in 1955. The Phase 1 Inventory covered the entire Green Area except for what was designated the Rocky Mountain Forest Reserve. It was based on 1949-1954 aerial photography and described the forest according to broad classes of crown closure, height, and species composition. No attempt was made to update the information from this inventory after its completion in 1956 (Lowe 1976).

Because the Phase 1 Inventory was not updated, it quickly became outdated. The Phase 2 Inventory was completed in 1966 using aerial photography dated from 1956 to 1966. It covered the southwestern and Rocky Mountain foothills and a large portion of the Green Area between 53°N and 57°N. Only smaller portions of land above 57°N were included in this inventory. The information collected from aerial photography was basically the same as that collected during the Phase 1 Inventory, with the addition of site class and maturity or age of stand establishment data.

About this time (mid-1960s), Alberta adopted a new system for timber allocation called the Quota System. Quotas are a percentage of the annual allowable cut (AAC) and are renewed every 20 years. A crash program known as the Quota Reconnaissance Survey was undertaken to identify the sawlog and near-sawlog sized stands necessary to allocate cutting for the next 20 years.

Phase 3 Forest Inventory

Because the quota system of tenure requires that quotas be renewed after 20 years, new AACs had to be determined by 1986. This meant that a reliable management inventory had to be in place by 1984. This led to the Phase 3 Forest Inventory. It was initiated in 1970 and covers almost the entire Green Area. The main purpose of this inventory was timber management planning at management unit, regional, and provincial levels as well as providing input to national statistics (Lowe 1979). Although primarily a timber inventory, the Phase 3 Forest Inventory was also designed to address forestry in a multiple-use context. It was also the first inventory that was designed to be progressively updated by incorporating growth and depletion information.

Specifications for the inventory are based largely on previous inventories, but they provide a greater degree of detail. The cover types include more descriptive features (such as understory descriptions and coniferous commercial classes) and the estimates of volume are more accurate. Inventory data are stored in a computer system that allows easy access and updating.

The inventory has responded to changing needs over time. In 1970, aspen and other hardwoods were considered to be weed species. Phase 3 concentrated on coniferous species, virtually ignoring the separation of hardwoods. In the mid-1970s, differentiation of hardwoods into aspen, poplar, and birch became part of the inventory specifications in response to increased interest in the aspen resource. In areas already completed before this change took place, significant updating to separate the hardwoods has occurred.

Methodology

As with most inventories, there are two components: mapping and volume estimation. Mapping involves airphoto acquisition, photo interpretation, ground truthing, area measurement, and map construction. Volume estimation involves stratification (based on the forest cover), ground sampling, compilation, volume table creation, and the necessary linking of results back to individual forest stands.

Interpretation and Mapping

The Phase 3 Forest Inventory was largely carried out using 1:15 000 leaf-on black and white modified infrared photography. Orthophoto bases were prepared using 1:60 000 black and white panchromatic photos. A double stereo model was then used to generate 1:15 000 orthophoto bases (Anon. 1986a).

Interpretation began with the identification of the productive forest base. Productive forestland is considered capable of producing a wood volume of 50 m^3/ha by age 140. Anything less than this is described as nonproductive and is generally divided into such categories as muskeg, scrub, water, rock, grassland, etc. Productive forest may or may not be stocked with trees. If not, it is generally a recent clearcut or burn and is labelled as such, with the year of disturbance.

Stocked productive forestland is described in much more detail. Crown closure, height class, species composition, coniferous commercial class, origin class, and site class are all described based upon airphoto and supplementary information available to the interpreter. Additional codes are available to describe certain stand conditions, disturbances, or steep slopes when observed. Separate overstories and understories can be described in detail (Anon. 1986b). Forest cover maps are generated by transferring forest cover interpretation to the orthophotos and then drafting the maps by hand.

Records of individual stands and their attributes (including area) are maintained in the Alberta Forest Inventory Storage and Maintenance System (AFORISM). In addition, depletions due to fire and harvesting are updated annually. Other depletions due to geophysical activity, major roads, etc. are updated approximately every 3-5 years, or just prior to allowable cut calculations. Updating of computer records takes place at the same time maps are updated, ensuring compatibility between the electronic data and the representative map.

Volume Sampling

Volume sampling for the Phase 3 Inventory was carried out on a regional basis. These distinct areas are called volume sampling regions (VSRs). Although they have some biological basis (i.e., separating foothills from boreal, north from south, elevation differences), they are largely administrative and were employed to ensure adequate geographic distribution of sample plots throughout the province. In accessible areas, ground plots (prism cruises) were used to obtain point estimates of volume. In inaccessible areas, considerable use of large-scale photography (LSP) resulted in the estimation of volume on a plot basis from the photos.

Within each VSR, plot estimates of volume were aggregated by unique strata to obtain an average volume. A unique stratum was defined by its cover group, density class, height class, and the first two major species. The resulting averages were assembled into cover type volume tables. These tables were then used in conjunction with the AFORISM stand lists to assign an average volume per hectare to each productive, stocked forest stand (Anon. 1986c).

This approach works well for planning needs at the management unit level. On smaller areas, the reliability of the volume estimates declines. As described earlier, this inventory was not intended for use at levels below the management unit.

Where are We Now?

Currently in place is a paper-map-based forest inventory designed primarily for timber management. We have a large computerized data base system for record keeping and for producing a wide variety of reports describing area and volume information. An established procedure for updating maps and computer records is used. In addition, other computing systems are used to access this information for calculating AACs.

Challenges

There are problems associated with using the Phase 3 Inventory for integrated planning. There are demands to account for other uses of the land and to evaluate trade-offs at very fine resolutions of scale - something this inventory was never designed to do.

With an inventory that uses rather broad classes to define stand types, we cannot use our sophisticated growth and yield models to update volume estimates. These growth models require estimates of stand age, height, and site that are finer in resolution than the current inventory classes provide. Other methods for "growing" the inventory are being tested, but so far we have not found a way of updating volume estimates between inventories.

The inventory is also aging. Our updating capability has historically been limited to depletion adjustments. Newly regenerated forests are not yet accounted for in the inventory. Again, we are working towards ways of rectifying this deficiency.

What's Next?

Integrated resource management is driving our latest inventory effort. Integrated planning and management will only be successful when the inventory describes the land and resources in a way that alternate uses, or combined uses, can be evaluated. In prototyping a new inventory, we not only wanted to address the problems faced with the Phase 3 Inventory but we also wanted to get information on the aspen resource that was outside the Phase 3 Inventory boundary. We recognized the need to map and sample these areas to manage that land on a sustained yield basis.

Alberta Vegetation Inventory

In 1986, we started work on the prototype Alberta Vegetation Inventory (AVI). This was our first successful attempt at bringing other disciplines into the inventory process. The result was a set of integrated specifications that could be used for forestry, range, or fish and wildlife planning. Agreement by the three line divisions in our department (Forestry, Fish and Wildlife, and Public Lands) was reached on how to describe ground vegetation in a way that was meaningful to all of these land and resource management agencies.

Cooperative Vegetation Inventory

Shortly after our AVI prototype inventory began, an industry/government task force was established to determine if agreement could be reached on a minimum inventory standard for holders of forest management agreements. This involved coming up with a set of inventory specifications that would serve the needs of both industrial and government forest and land managers. The AVI specifications were modified slightly, resulting in agreement among the participants. This new effort was named the Cooperative Vegetation Inventory (CVI) because of the shared nature of the program.

Specifications

Forestry specifications include refinements to the Phase 3 Inventory system: crown closure is recorded as in Phase 3; stand height to the nearest metre (in 3 m classes); species composition by 10% classes; origin class (10 year classes); stand structure (and percent in each layer); site class based on updated, species specific site index curves; and moisture regime. Stand structure was added to account for the variability in volume estimates usually associated with two specific types of stands. The first type is called horizontal structure and is the result of small dissimilar stands being lumped together because of mapping limitations, i.e., they are too small to map individually. In these cases, each component is described individually and its proportion of the total stand area recorded. The second structure is called complex and consists of stands with a wide range of tree heights. The many-layered heights of these stands form a pattern or mosaic that cannot be described using the two-story or horizontal designation.

Lands not covered by forest are described according to their ground cover. Man-made changes are also documented and described, e.g., cultivated, pasture, annual crops, settlements, and industrial development are all interpreted, coded, and recorded (Anon. 1989).

The CVI is unique in the history of Alberta inventories in that it is the first to provide digital products. Custom maps showing wildlife habitat, forest cover, etc.

can be derived from the spatial and attribute data base. The value of a digital inventory is being recognized everywhere, and the growth of geographic information systems (GIS) in forestry applications is ample evidence of this.

The CVI specifications are the basic information that each participant provides in a common format. Any party can add additional attributes that they need for their own purposes - the CVI provides only the base information. For example, stems per hectare may be added to an individual's inventory, but this is not part of the basic specifications.

Implications

The implications of where we are going with inventories is evident when we look at trends in information and management needs. The objectives of our successive inventories have shifted from pure forestry needs (in a single-sector sense) to assessing forestry first within the framework of multiple use and now in the context of integrated management. In terms of inventory specifications, this has led to describing smaller and smaller units of land (from 65 ha in the Phase 1 Inventory to 2 ha in the CVI). We also want to know more about these areas, as shown by the increasing number of variables described by the inventory. Not only do we want to know more about smaller areas but also the resolution of what we want to know has increased. For example, the definition of height class has dropped from 12 m to 3 m, stand structures are described to better stratify volume estimates, and the detail in which we describe nonforested land has increased substantially.

Conducting inventories is an expensive business. We recognize the need to rely more on models and modelling to grow our forests rather than on reinventorying. The CVI specifications are certainly more useful in a modelling sense than the Phase 3 Inventory specifications. The CVI is more capable of identifying stand merchantability as well as providing attributes that are more closely aligned with our current growth and yield model inputs.

As the CVI gets under way, the amount of attribute and spatial data that needs to be stored will increase rapidly. This has convinced us of the need now for a manageable data system to maintain the records. A data base standard is now under development that will help make the CVI a success. In the long term, the forest inventory data, both spatial and attribute, will be tied to the department-wide Land Related Information System (LRIS). Through a computer network, information users can access the primary information, which is composed of digital maps, land status information, and survey control data. The gateway also allows user access to the thematic systems of which forestry is just one of many. However, the fundamental concept that has emerged from government/industry discussions is that a joint forest management information system not only shares forest information but also other data as well (survey control, topography, ownership, hydrology). The LRIS concept provides the framework on which to develop the cooperative forest inventory.

If the CVI is as successful as we hope, our reliance on the Phase 3 Inventory may quickly fade. The majority of the Green Area is, or will be, under forest management agreements with industry. Given the generally cooperative attitude between government and industry in our province, an updated vegetation inventory, more suitable for integrated planning and decision-making, will be available in a fraction of the time it would take government to complete the inventory alone.

We're not there yet, but we have the commitment from industry and government to participate in a cooperative effort that will enhance our knowledge and decision-making abilities in the area of resource management.

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Counting the Trees is Not Enough: Measurement and Projection of Economic Timber Supply

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Abstract

Conventional methods of assessing and projecting timber supplies are essentially measures of the physical dimensions of the resource. A more useful measure of timber supplies can be obtained by considering the economic dimension of the forest inventory and the interaction between the biological and economic dynamics of the forest. This approach, implemented in the price responsive timber supply model, is demonstrated for a coastal timber supply area of British Columbia. The extremely price sensitive nature of the economic dimension of Canada's timber resources implies that future levels of supply will be determined by market prices and the costs of inputs to harvesting, rather than by conventional forestry processes of accruals and depletions.

Résumé

Les méthodes traditionnelles de mesure et de prévision de la réserve de bois sont essentiellement des mesures des dimensions physiques de la ressource. On peut obtenir une mesure plus utile de la réserve de bois en tenant compte de la dimension économique de l'inventaire forestier et de l'interaction entre la dynamique biologique et économique de la forêt. Cette approche, appliquée à un modèle de réserve de bois sensible à la tarification, est présenté dans une région d'approvisionnement en bois sur la côte de la Colombie-Britannique. La nature extrêmement sensible à la tarification de la dimension économique des ressources forestières du Canada suggère que les niveaux futurs de réserves seront déterminés par les prix du marché et le coût des facteurs de production de la récolte, plutôt que par les méthodes d'accroissement et d'épuisement utilisées traditionnellement en foresterie.

Introduction

The fact that the current and future size of Canada's timber resource is controversial and so poorly understood must seem very odd to the general public as well as to other resource industries. The questions Are we running out of Trees? and Are we practicing sustained yield forestry? appear to be such simple ones. Why can't we simply count the trees?

Over the years, despite substantial effort and expense to do just that, we have generally obtained the wrong answers.

In 1864, for example, the Anderson sawmill on the Alberni Canal of Vancouver Island closed because "there is no timber left in the district"; yet, in the last 5 years, the Alberni region has supported an annual harvest of 2.8 million m^3 (MacKay 1982). After 150 years of continuous harvesting in the Alberni region, surely there is less wood, or at least fewer old growth stands. What happened?

Well, what happened is that the economic dimensions of the timber supply have expanded much faster than the physical dimensions have contracted.

Methods used to forecast timber supplies have continued to ignore or at least underplay the economic aspects of the resource. The best documented (although hardly unique) examples of this mode of thinking are the timber supply outlook studies conducted by the United States Forest Service for national planning purposes. For many years, until the early part of the last decade, the United States Forest Service undertook timber supply studies that extrapolated past harvest levels to forecast a future level of demand for roundwood. This demand was then compared with a projection of the future availability of roundwood. Inevitably, a "gap" between future supplies was identified and a "timber famine" was predicted. However, the gaps and the famines never materialized. Timber production appears to have grown without interruption, and no major shortfalls have occurred. What happened?

What happened is that increasing roundwood prices and decreasing costs of inputs to the harvesting process (such as labour, energy, and capital) have made additional sources of supply available. Increasing prices may also have discouraged demand, so that supply and demand have equilibrated.

When our supplies of timber are measured, traditionally the physical dimensions of the land base and inventory have been stressed, with no attempt being made to count the trees. Our timber supply models simulate the biological dynamics of the forest, but ignore the economic dynamics of the forest industry. This continues to be the case in spite of the fact that 100 years of forest regulation in North America has demonstrated that economic factors, not biological factors, are the dominant determinants of timber supply levels, within the ultimate physical limits of the forest.

This lack of appreciation of the economic nature of the timber resource has contributed to the development in Canada of a doctrine of scarcity of timber, or impending scarcity - a view of timber supply that has been accepted by the public, elected leaders, and much of the forestry profession. This opinion has been broadcast internationally and has possibly resulted in the loss of potential investment, the loss of markets, and benefitting our competitors.

There is a different story to tell about timber supply, one that is somewhat more complicated and conditional, but more complete and much more useful for understanding the future. Understanding the future industrial supply of timber is becoming increasingly critical as we contemplate the placement of major investments in forest production and processing and are called upon to allocate portions of the forestland base to nontimber uses.

The objective of this paper is to attempt to tell the "complicated and conditional" story of timber supply and to demonstrate how we can improve our measurements of current timber stocks and projections of future supplies by including in our analysis some basic economic principles. The first section of the paper outlines some basic concepts of economic timber supply and describes their implementation in a computer model. In the second section, the approach is applied to a portion of the British Columbia coast. The final section discusses the economic dimensions of Canada's future timber resource and presents some recommendations.

Modelling Stocks and Flows of Timber

Before proceeding, it is necessary to clarify the meaning of some of the terms commonly used to describe the magnitude of the timber resource. In this paper, "timber supply" is used in its economic sense, as the rate at which timber will be made available for harvesting in response to a range of product prices. Timber supply is the flow of timber from the forests to the processing plants and should not be confused with inventory levels, which are measures of the physical stock of timber. The biological productivity of a forest is the rate at which timber stocks are replenished after depletion, sometimes referred to as the physical timber supply. Annual allowable cut (AAC), the conventional measure of timber supply, is generally a measure of economic supply determined by reducing the physical supply in an ad hoc procedure.

It is useful to think of timber supply as having a number of economic dimensions, in the sense that supply expands or contracts along these dimensions. These economic dimensions include the

- extent of the forestland base
- intensity of production (growth rate)
- intensity of utilization of the tree
- intensity of utilization of the forest stand (marginal species)
- intensity of protection

Each of these dimensions can be adjusted through expenditure (either investments or by incurring additional operational costs), and each has a margin or point beyond which further expenditure is economically counterproductive. These margins move in response to the cycles and trends of the demand for forest products in that a higher price for roundwood (or lower costs of harvesting inputs) can justify larger investments or higher costs of recovery.

To forecast future timber supplies, one must consider the response of the supply to changes in price and costs at each margin, the physical constraints on each dimension, and a schedule of future prices, costs, and investments.

This approach to forecasting timber supplies may seem devoid of forestry, but it isn't. Modelling the behaviour of the margins requires that forest dynamics be fully represented.

This approach to the analysis of timber supplies is the basis of a current Forestry Canada project designed to develop a regional timber supply model to be used for national assessments. The approach is referred to as price responsive timber supply and the model, therefore, has been deemed the price responsive timber supply model (PRTSM).

The PRTSM considers each of these economic dimensions, but focuses on the first one, i.e., the extent of the forestland base. The PRTSM will not be described in detail in this paper, but it is necessary that some of its key features be understood to comprehend the few results that will be presented to support the main arguments of this paper.

In addition, data from a British Columbia coastal timber supply area (TSA) are used to demonstrate the major points made in the paper. It is not the purpose of this paper to make a statement about rates of harvest in this particular TSA or anywhere else on the British Columbia coast. The TSA is used here as a case study because it offers a high quality data set and because it presents a dramatic example, although somewhat extreme, of the price responsiveness of timber supply.

Case Study: Economic Timber Supply on a Coastal TSA

Of the total productive Crown forestland in the North Coast TSA, only 14% was determined to be operable in a recent assessment (Williams 1988) and another 6% was set aside as being environmentally sensitive, for roads, or because of insufficient forest cover. The remaining 80% of the land base was reserved from tim-

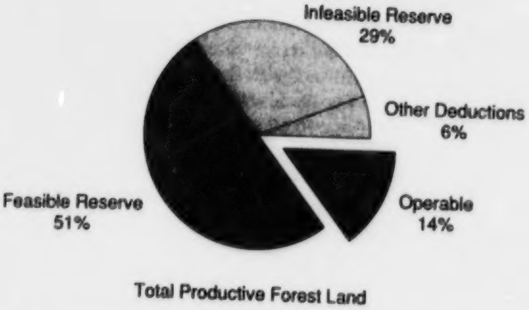

Figure 1. Classification of the total productive Crown forest of the North Coast TSA.

ber harvesting for economic reasons - high operating costs, low timber values, or a combination of both (Figure 1).

The margin between the operable and inoperable reserve was established by appraising the forestland base; the delivered wood cost (stump-to-mill), market value, and conversion return (net value) were estimated for each of 40 000 inventory records. These "appraised" stands were sorted into operable (positive conversion return) and inoperable (negative conversion return) categories. The marginal stand has a conversion return of zero and the proportion of operable stands in the forest inventory is the extensive margin.

Although the main objective of this exercise was to establish the extensive margin, it was also possible to estimate the sensitivity of the margin to changes in the market value for timber. It was found that a 1% increase in price would result in a 4% increase in the operable land base. This result indicated that the operable land base was highly sensitive to the price of roundwood and the costs of inputs to harvesting. This result concurred with the results of an earlier study undertaken for the entire coastal region of British Columbia (Williams and Gasson 1986).

The appraised inventory strata were sorted into categories of forest types, sites, and operating cost (Figure 2). The rate and extent of the shift of the extensive margin with increasing or decreasing prices differ for each of these land categories according to the shape of the distribution of area over conversion return.

To forecast future timber supplies, one must consider two questions. First, as we proceed to harvest (and manage) the operable land base, Will the economic characteristics of the land base change, i.e., will the regenerated land base remain operable or become inoperable? Second, How will the movement of the extensive margin in response to price and cost trends affect our forecast of timber supplies?

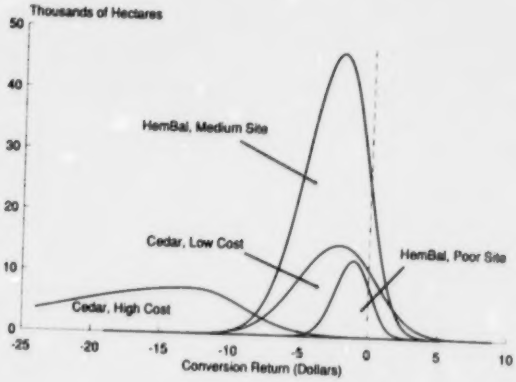

Figure 2. Distribution of operable timberland for forest categories of the North Coast timber supply area.

Both of these questions can be addressed using the PRTSM. The first step in the PRTSM supply cycle is to identify the operable land base as a function of the current market price (or derived price) for roundwood (Figure 3).

Old growth and growing stock timberlands are modelled differently. For the purpose of this modelling exercise, old growth is standing stock that is relatively stable, i.e., it will not grow, deplete, or change in terms of cost or value markedly during the time period prior to its first harvest. Old growth timber will continue to provide much of the harvest for the next 20 years, so old growth analysis units are modelled in a manner that emphasizes the static cost (and value) detail and largely ignores the biological dynamics of the old growth stands.

Old growth analysis units are considered to be of one age and are represented as a distribution of area

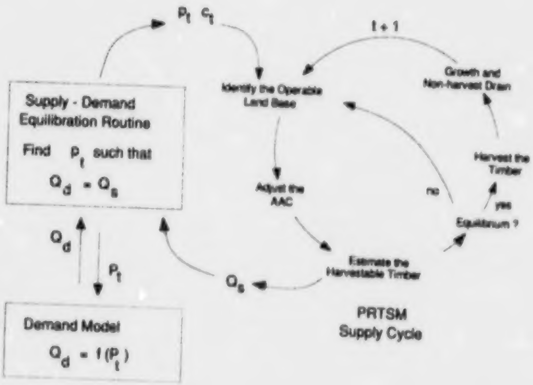

Figure 3. The price responsive timber supply model (PRTSM) linked to a demand model through a price-quantity equilibration procedure.

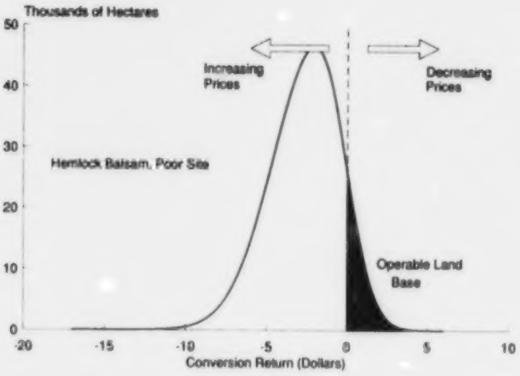

Figure 4. Adjusting the margin of operability of old growth.

and volume per hectare over a range of net value (Figure 4).

An old growth stand is considered to be in the operable land base if it produces a positive conversion return. For any year in the projection period, the operable area of old growth is adjusted by using the current market price and operating costs to shift the margin. Increasing prices shift the margin to the left, increasing the operable area, whereas decreasing prices shift the margin to the right.

Growth stock stands are considered to be within the extensive margin if, an any time during the life of the stand, the conversion return is positive (Figure 5). At the base price level used to create the stand value curve illustrated in Figure 5, the stand becomes operable at 150 years of age. Therefore, hemlock and balsam medium site stands are included in the operable land base.

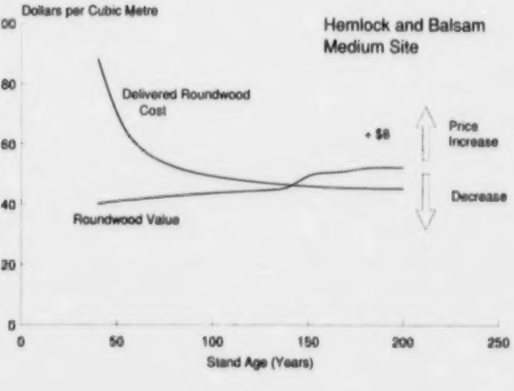

Figure 5. Adjusting the margin of operability of growing stock.

For any year in the projection period, the operable area of growth stock is adjusted by using the current market price to shift the stand value curve. The cost curve may also be shifted with the current operating costs. Note that on Figure 5, an $8 increase in price drops the operable age to 80 years.

The next step in the simulation cycle is to adjust the AAC based on the current (adjusted) land base. Establishing an AAC usually entails consideration of political and economic factors in addition to parameters of forest productivity. Therefore, the strategy adopted for the PRTSM is to incorporate current AAC levels and harvest forecasts developed by the province, and to adjust the harvest forecast subject to the provincial harvest flow policy. The harvest forecast is adjusted through a set a rules that considers the AAC of the previous projection period and the long run sustained yield (LRSY). Changes in market price cause an adjustment in the operable land base, and the LRSY is recalculated for the adjusted operable land base. The harvest forecast is then adjusted to reflect changes in the LRSY.

The rest of the simulation cycle (Figure 3) is straightforward and conventional. The harvest is located and removed from the inventory, growth and non-harvest drain are accounted for, and the simulation clock is moved ahead one time period.

The PRTSM can obtain its market prices as a simple list provided by the user, or it can link to a demand model and provide an integrated supply-demand analysis. The PRTSM was designed to link to the North American timber assessment market model (NA-TAMM; Phelps 1990) which is an extension of the TAMM (Adams and Haynes 1980) used by the United States Department of Agriculture Forestry Service for their 5-year program of forest resource assessment. Forestry Canada intends to use the PRTSM in combination with the TAMM to undertake regional analyses of timber supply and demand.

In Figure 6, results of the price responsive approach are compared with a conventional physical timber supply analysis of the North Coast TSA. The British Columbia Ministry of Forests method of forecasting harvests reveals that the current harvest can be sustained for up to 50 years before declining to its LRSY. The initial phase of harvesting above the LRSY occurs due to the preponderance of old growth timber in the TSA.

However, using the same initial operable land base, the same yield curves, and the same policy flow constraints, and assuming that prices and costs will remain constant, the PRTSM indicates that harvests will begin to decline in about a decade, eventually reaching a reduced LRSY in about 50 years. The explanation for this is that under the scenario of constant prices and costs, some portion of the stand, which is operable as

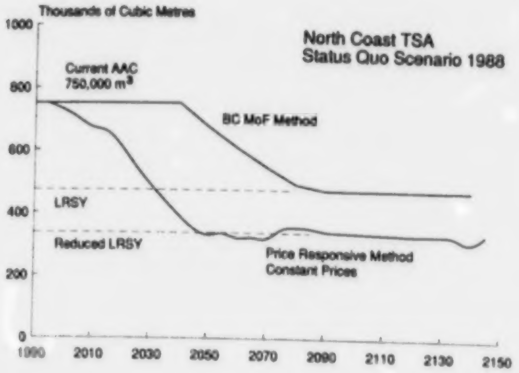

Figure 6. Adjusting the harvest schedule in response to changes in the operable land base.

old growth, will never become operable as second growth, at least during the 150 year simulation period of this analysis. Thus, under constant prices and costs, the operable land base shrinks.

What expectations should we have for future operating costs and roundwood values?

There is little evidence that input costs to harvesting are increasing in the long term. Across North America, the cost of harvesting has remained constant or declined slightly over the last four decades, in spite of the steadily worsening biophysical characteristic of the resource. This implies that input costs have held steady or decreased, probably due to technological improvements in the harvesting process. During the 1960s and 1970s, the British Columbia coast did experience rising costs, but over the last decade costs have held steady or declined. Consequently, we may conservatively assume that operating costs will remain relatively constant in terms of real dollars.

The long-term trend in timber prices is a bit more complicated. Sedjo's (1989) review of the literature on this topic found that the price of industrial wood in North America increased at a rate of around 1% annually between 1900 and 1950, but has since slowed considerably to about one third of that rate.

Figure 7 shows the results of the PRTSM analysis of the North Coast TSA under a scenario of prices rising at 0.35% per year. Note that the harvest levels rise steadily starting about 5 years from now, and after a period of liquidating old growth, settle out to a LRSY about 20% higher than current harvest levels.

Harvest forecasts under both price scenarios can be explained by tracking the movement of the extensive margin (Figure 8). Under the scenario of steadily rising prices, the extensive margin rapidly expands into the

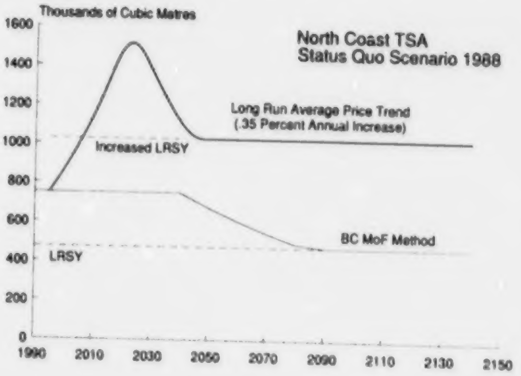

Figure 7. Harvest forecast using the PRTSM, assuming an annual real price trend of 0.35%.

reserved old growth, converging asymptotically with its physical limit about 150 years from now. As more old growth area is brought into the operable land base, the LRSY increases and the AAC is adjusted upwards.

Conclusions

The North Coast TSA example demonstrates the main argument of this paper, that the economic dimension of the timber resource may be markedly different from the physical dimensions and that the operable margin is extremely price (cost) sensitive. These concepts are used in the following section to characterize Canada's timber supply.

Canada's Timber Supply

After a couple of hundred years of harvesting, Canada still has enormous forest resources. Under current economic conditions, only a portion of this resource is operable, but the margin of operability is extremely price and cost sensitive. If long-term trends continue, i.e., improving prices for wood and stable or declining

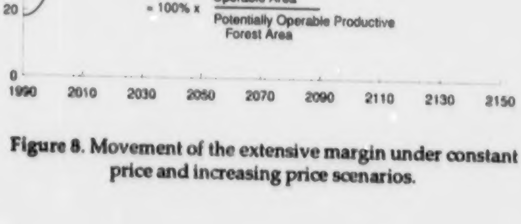

Figure 8. Movement of the extensive margin under constant price and increasing price scenarios.

costs of recovery, the operable land base will expand out to its physical limit and the supply of wood will increase substantially. If the real price of wood remains stable or declines, or if costs increase disproportionately to price, the operable land base will contract and timber supplies will be reduced.

Under the optimistic scenario, as prices increase we will use some portion of the price to pay for moving the extensive margin, in terms of higher operating costs. At some point, and in some cases at the present time, it will become advantageous to place our investments on the other margins to increase growth rates, improve utilization, or improve forest protection. In fact, we already invest in each of these dimensions of our timber supply, but extensive forestry is still the dominant strategy for industry expansion in Canada.

The most unsettling implication of this story is that our future supply of wood (and our forest-based economy) will be largely determined by future prices of wood products and the cost of inputs to the harvesting process. Will a competitive source of supply suppress or reverse long-term price trends? Will developing economies boost the demand for forest products and accelerate price increases? Will technological advances continue to control or reduce harvesting costs? These issues are studied by very few people in Canada, yet they are of critical importance to the future of our forest industry.

Another snag in this tidy story of expanding margins and shifting investments is the issue of withdrawal of large and contiguous portions of the forestland base from harvesting for preservation as wilderness and parks. Proposed land withdrawals are usually complete watersheds; therefore, they include a cross section of operable and inoperable timber lands. Under the optimistic scenario of rising prices, expansion of the operable land base may compensate for withdrawals, and timber supplies will be sustained. If large-scale land withdrawals are followed by price declines, supply will become very tight, very fast.

Finally, this description characterizes Canada's timber supply in terms of the values and costs of harvesting timber. Forestland is treated as an input to the timber production process and the values of nontimber resources are ignored. This perspective is no longer adequate. Society is assigning substantial values to the nontimber benefits of forestlands and it seems unlikely that this trend will change. Other resource values must be integrated into this timber supply story to rationally allocate forestland among timber and nontimber uses.

This timber supply story depends on price cost. It does not follow that conventional inventory and growth and yield information is irrelevant to the questions posed earlier regarding whether we are running out of trees and whether we are practicing sustained yield forestry. Conventional forestry measurements are necessary, but are not sufficient for assessing future timber supplies. None of the questions posed in this paper can be adequately addressed without considering the cost of recovery and the value of the forest inventory, and trends in input costs and forest product prices.

Recommendations

To measure the economic dimensions of Canada's timber resource in future studies, the following recommendations are offered.

1. Include economic factors in forest inventories.
   Variables should be included in forest inventories that will allow estimating stump-to-mill costs and the value of the roundwood at the mill. One of the most important variables is geographic location, which is required to estimate log transportation costs.

2. Incorporate explicit economic reasoning into measurements and forecasts of timber supplies.
   Measurements and forecasts of timber supplies should consider delivered wood costs and roundwood prices explicitly. Timber supply models should simulate the interaction of the forest's biological dynamics with the economic dynamics of the forest industry. This doesn't need to be complicated. At the management unit level of analysis, incorporation of price and cost schedules should be sufficient.

3. Standardize timber supply terminology across the country.
   Many of the terms used to describe timber supplies, such as AAC and LRSY, have significantly different meanings from province to province.

4. Study trends in harvesting technologies, operating costs, and world markets to forest products.
   The economic dimensions of Canada's forest resource in the year 2050 will be determined largely by operating costs in Canada and price levels in foreign markets; growth, yield, and inventory levels will continue to be of secondary importance.

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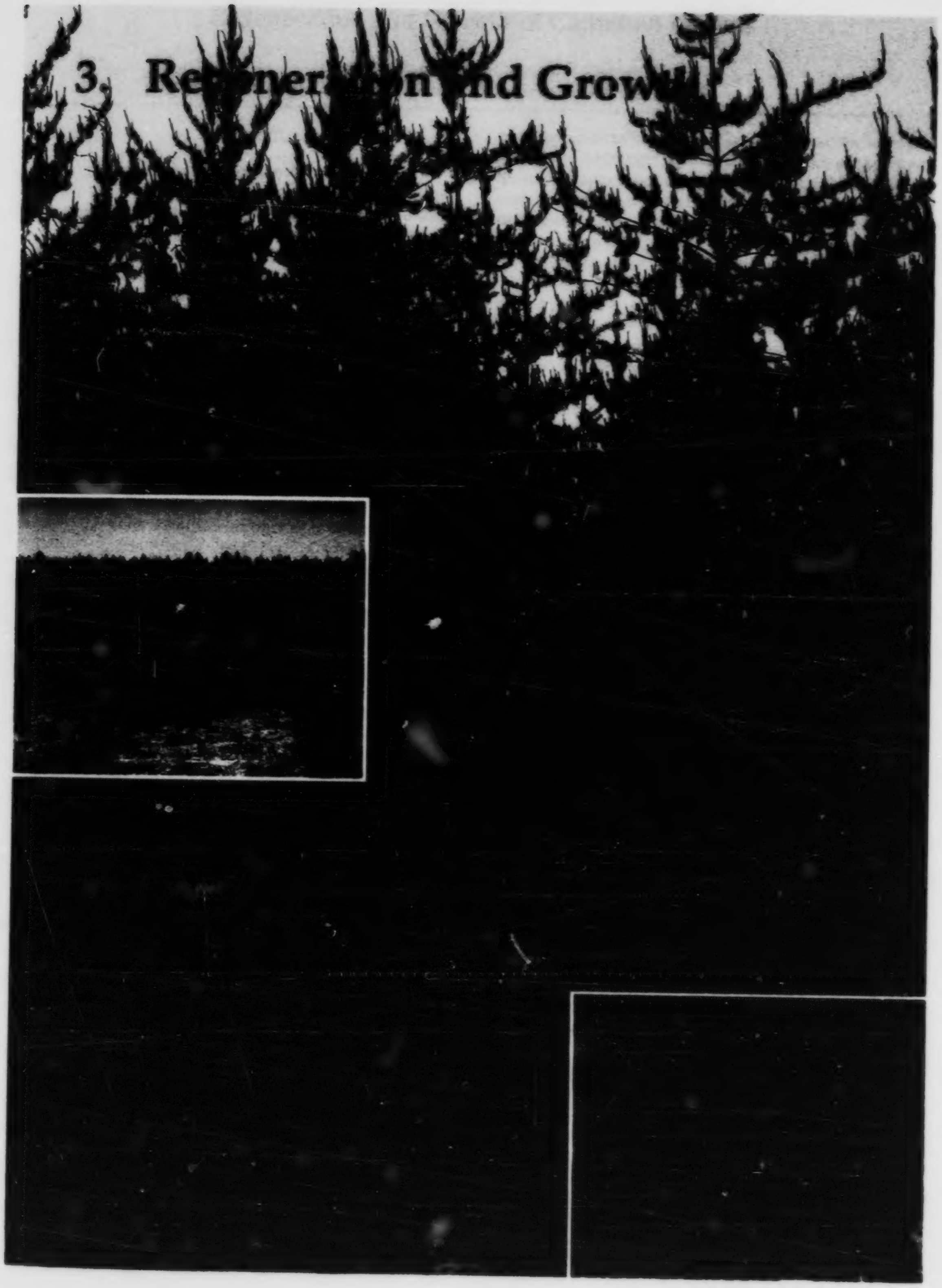
3. Regeneration and Growth



Regeneration and Growth of Canadian Forests

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Abstract

The Canadian forest is a heterogeneous landscape. Climate, physiography, and disturbance control the distribution and growth of forest types. Processes of forest regeneration and growth are linked to these basic factors in the natural forest, but they change or become uncertain in response to human intervention, particularly forest harvesting. Studies of forest regeneration indicate that some forest types regenerate successfully after harvesting, but others do not, leading to changes in the length of the regeneration period, species composition, or growth rate relative to natural forests. Although case studies have indicated that these changes are, in fact, occurring, little systematically collected data are available to quantify the degree of the changes being created in the Canadian forest by human intervention. Artificial regeneration has been used to counter these problems, but the inherently slow growth of Canada's boreal and subboreal forests limits the amount of investment that can be applied to forest management. Growth estimation is a necessary precursor to large-scale forest management decisions, but current techniques have been almost entirely based on measurements made in naturally established forests. This does not lead to accurate forecasting of the development of postharvest naturally or artificially regenerated forests. Recommendations are made that Canada needs to rethink its currently fragmented approaches to forest research, forest monitoring, and growth estimation. Only a concerted, coordinated approach will provide an adequate description of forest dynamics and prediction of future development of the forest resource.

Résumé

La forêt canadienne offre un paysage hétérogène. Le climat, la physiographie et les perturbations régissent la répartition et la croissance des types forestiers. La régénération et la croissance des forêts sont liées à ces facteurs fondamentaux en forêt naturelle, mais se modifient ou deviennent irrégulières à la suite d'interventions humaines, notamment de la récolte. Des études de la régénération des forêts révèlent que certains types forestiers réussissent à se régénérer après la coupe, contrairement à d'autres, ce qui amène des modifications de la durée de la période de régénération, de la composition des espèces ou du taux de croissance par rapport aux forêts naturelles. Bien que des études de cas aient révélé que de tels changements se produisaient réellement, nous disposons de peu de données systématiques pour quantifier le degré de changement engendré ainsi dans la forêt canadienne par l'intervention humaine. Pour remédier à ces problèmes, nous avons fait appel à la régénération artificielle, mais le taux naturellement lent de croissance de la forêt boréale et sub-boréale canadienne limite le montant des investissements que l'on peut consentir au chapitre de l'aménagement forestier. L'estimation de la croissance est un prérequis à toute décision d'importance relative à l'aménagement forestier, mais les techniques actuelles sont presque toutes fondées sur des mesures prises en forêt naturelle. Cela ne permet pas de prévoir avec précision le développement des forêts régénérées naturellement ou artificiellement après la coupe. Les auteurs recommandent que le Canada revoie ses approches actuellement morcelées en matière de recherche, de surveillance des forêts et d'estimation de la croissance. Seule une approche coordonnée et concertée permettra de décrire adéquatement la dynamique de la forêt et de prédire le développement futur des ressources forestières.

Introduction

The Canadian forest is one of the largest in the world, accounting for 10% of the world's forest area. Stretching from the northern tundra to the prairies and Carolinian forests of the south, and from the Pacific coastal rain forests to the spruce-fir forests of the Maritimes, it contains a multiplicity of forest regions and stand types. Discussion of the growth of this diverse forest requires consideration of the climate, patterns of natural and man-induced disturbance, genetics of the tree species, and current and potential effects of harvesting and silvicultural programs.

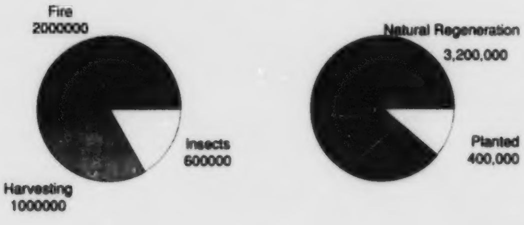
No one is particularly interested in how many million cubic metres of wood are potentially grown in Canada each year. Such a number would be meaningless because there is no national regulation of timber production. There are, however, a number of issues of national significance that relate to the growth of Canadian forests. These include the relative rate of growth of Canadian forests versus those of our international competitors, the composition and rate of growth of forests after harvesting as opposed to forests of natural origin, the impact and effectiveness of silvicultural treatments used as tools in the management of forests, and the monitoring and prediction of forest growth as it relates to stress responses and the yield of forest products. Earlier studies have examined issues related to the growth of Canadian forests based on catalogues of forest production (Bickerstaff et al. 1981) or case studies of different regions (Reed 1978). This paper will discuss these issues from the perspective of landscape patterns and suggest where critical information is currently lacking regarding the growth and functioning of Canadian forests.

Distribution and Composition of the Canadian Forest

The nature of Canada's forest is primarily determined by two forces, climate and disturbance. The principal climatic factors that govern the distribution of species are water balance, as defined by Thornthwaite (1948), and radiation (including both heat and light energy). The water balance results from the difference between precipitation and evapotranspiration and indicates the degree of drought occurring in different regions. Radiation absorbed by a forest is largely determined by latitude and elevation. These climatic factors control species distribution by their relationship with disturbances, such as fire; by their control of seed dissemination and germination; and by their affect on the outcome of competition among species.

The major natural forces of disturbance that control the forest landscape are fire, wind, and insect infestation. Fire is strongly related to climate, principally as it effects fuel moisture. Simard (1973) produced a map of fire weather zones for Canada that correlates reasonably well with the distribution of balsam fir forests in the east (very low to moderate fire weather) and pine-spruce forests in the west (moderate to extreme fire weather). A second major disturbance force is insect epidemics, such as that brought about by the spruce budworm or by western bark beetles. These infestations are naturally occurring phenomena, usually cycling forests when fires are rare or absent for long periods of time. In the east, for example, major fires are rare; thus, the balsam fir - spruce forests are almost entirely regenerated by spruce budworm epidemics.

Over the past century or so, humans have begun to play a major role in forest disturbance as well. Harvesting of forests, for instance, now accounts for about 1 million ha/year (Figure 1). The effect of harvesting as a landscape process is very different from that of fire or insect epidemics. Harvesting tends to occur in waves or concentric patterns on the landscape, and the regenerated forest often differs in species composition from that regenerated following natural disturbances (Frisque et al. 1978; Jeglum 1983; Brumelis and Carleton 1988; Whynot and Penner 1990). In addition, the application of intensified silviculture programs (e.g., planting, weed control, and juvenile spacing) will lead to changes in stand density and species composition in the small proportion of the forest where they are applied (Fig. 1). Human activities also affect the forest landscape through fire suppression and pest management, and through the introduction of exotic tree species, insects, and diseases.



Disturbance

Regeneration

Figure 1. Dynamics of Canadian forests.

Forest Regeneration

As noted above, patterns and processes of regeneration by forest species are linked to disturbance and climatic conditions. Several species regenerate after fire, and jack pine, lodgepole pine, black spruce, aspen, and birch have evolved mechanisms that lead to rapid recolonization of sites after burning. These mechanisms include stored seed, root suckering or stump sprouts, light seed, serotinous cones, rapid early growth, and multiple flushing or indeterminate growth. After fire, these species produce dense, rapidly growing stands that quickly dominate the site and overtop slower growing species. Similarly, after insect attack, balsam fir and red spruce are well adapted to regenerate from understory seedlings that rapidly respond to increases in light intensity. Western coastal forests, high elevation forests, and southeastern mixed forests are more stable ecosystems and regeneration tends to be a more continuous process. In these cases, the primary disturbance agents are surface fires, windstorms, root rot, or endemic insect populations that kill individual trees or small groups of trees.

After harvesting, many forest types, such as jack pine or lodgepole pine, regenerate in a fashion similar to stands of fire origin. In many other cases, however, clear-cut logging will remove seed sources, release buried seed in the forest floor, or give a competitive advantage to species such as pin cherry, aspen, or alder that are normally less prevalent. Slash burning can also affect regeneration if seed stored in cones in the slash is destroyed. Humans have tried to counter the imbalance caused by harvesting through silviculture activities that either provide seed/seedlings of a desired species via planting or direct seeding, or that prepare site conditions to encourage natural regeneration of desired species.

Growth of Canadian Forests

The growth rate and longevity of forests vary with climate, soil conditions, stand density, species composition, and the presence of insects or diseases. Climate has an overriding influence on potential forest productivity, both directly and indirectly. Broad regional differences in water balance and radiation input again define major differences in growth rate across the country. Within a forest region, individual sites vary in growth due to parent material, soil texture, and other factors that have been the basis for site classification schemes (Hills 1952; Pojar et al. 1987; Zelazny et al. 1989). Weather, as opposed to climate, varies from year to year, and growth histories of individual stands indicate that productivity varies from year to year in response to temperature and droughts.

Tree species vary in their inherent growth rates because of differences in resource allocation (i.e., between growth and storage), growth efficiency (i.e., growth per unit of light or nitrogen, for example), or growth pattern (i.e., determinate versus indeterminate). Thus, species such as jack pine have rapid early growth and short longevity (Fowells 1965), whereas species such as white pine, white spruce, Douglas fir, or yellow cedar have longer life spans, remain in a productive growing phase longer, and tend to accumulate more total biomass or wood volume in the stand. Within a given stand type, the growth rate of individual trees varies as a function of stand density. Trees in dense stands must share light, moisture, and nutrients among the individual trees. Usually, this competition process has a greater impact on the smaller trees in the stand and less effect on the larger, dominant stems (Brand and Magnussen 1988).

Growth is also modified by the presence of a host of secondary factors, including sublethal herbivory by insects and animals, chronic diseases and rusts, parasitic plants (e.g., mistletoe), and weather-related events, such as ice damage or hailstorms. On the other hand, beneficial relationships are found between trees and symbiotic fungi or nitrogen-fixing organisms.

Regeneration and Growth in Relation to Timber Production

Canada's natural forest resources have provided a source of high value industrial roundwood for decades. Concentrated harvesting in certain regions, such as the mature white pine forest, the coastal Douglas fir forest, and the tolerant hardwood forest, has substantially changed the regional character of the landscape. The degree to which harvesting has impacted on the nature of the forest in its largest sense, however, is debatable. Management intervention can increase or decrease the growth rates of forested areas. The increases generally result from control of stand density, silviculture inputs and, in some cases, change in species or genotype of the forest. Decreases in timber production have been attributed to physical degradation of harvested sites; improper silvicultural practices, such as tree species selection; and changes in the susceptibility of stands to insects, diseases, animals, and weed competition.

Issues in Forest Regeneration

The objective of forest regeneration after harvesting is usually to establish a stand of similar or preferable species composition within the shortest possible time frame. Undesirable change in species composition after harvesting has been a particularly common problem in Canada. Although areas quickly revegetate after cutting, it is often poor quality hardwoods or shrubs that colonize the site. From a timber production perspective, this represents a failure or delay in reestablishing the crop, and reduces the value and volume of the harvestable increment from the forest as a whole.

A number of case studies have been undertaken in different regions to examine forest regeneration after harvesting. Wall (1983) studied areas that had been salvage-harvested in the Cape Breton highlands after budworm epidemics. He found that harvested areas were not fully stocked with balsam fir, and that seral species, such as pin cherry, raspberry, and birch, had overgrown the conifers. However, by 15 years after harvesting, the deciduous species were declining and the balsam fir was becoming dominant on the site. Frisque et al. (1978) conducted a similar study of 36 pulpwood harvested stands in Ontario, Quebec, New Brunswick, and Nova Scotia. They found, 10 years after harvesting, that all areas had at least 2500 stems/ha, that the bulk of that reproduction was established before harvesting, and that some site types (notably mixed wood sites) were dominated by hardwoods and brush. They used a simulation model to show that projected yields from these naturally regenerated cutovers would be lower than from the previous forest, and that the forest would take longer to reach a merchantable state than after natural disturbances.

The effect of regeneration delay in British Columbia was quantified by Smith (1988) as shifts in the equations used to predict natural forest yield. He used British Columbia Ministry of Forests survey records to estimate the time required before harvested areas become sufficiently regenerated. After that point, the growth function would indicate convergence to the same total yield as the British Columbia Ministry of Forests volume-age curves. Mean annual increments on medium-good quality sites using Smith's calculation ranged from 0.4 to 3.2 m in the interior to 1.1 to 6.5 m on the coast. These figures are less than half of those presented on growth and yield estimate curves for naturally established coastal Douglas fir (Mitchell and Cameron 1985) and lodgepole pine (Goudie et al. 1990), for example. The difference largely results from dividing similar final yields by longer rotation ages.

Pearse et al. (1986) also looked at the dynamics of naturally regenerating land. In British Columbia, they estimated that only 40% of harvested areas will regenerate naturally. Their balance sheet showed that by 1987, increased reforestation rates would be sufficient to regenerate all areas harvested and would begin to reduce the total area of unstocked land. Although their study used some very large assumptions, it is so far the only attempt to establish a real balance sheet on regeneration activities in Canada.

The entire discussion on forest regeneration and plantation establishment has been clouded by a plethora of confusing terminology ("not sufficiently regenerated," "unstocked," "stocked but not free-growing," etc.). It was this problem with terminology that initiated the concept of the free-growing plantation. Foresters have long been concerned with the density of new stands and whether such stands were sufficiently stocked with commercial tree species. Increasingly, the standards for regeneration success include measurement of competing vegetation, assessment of the most ecologically appropriate species for the site, and determination of acceptable growth performance. These more detailed survey procedures lead to improvements in describing how the forest changes in response to harvesting and, where necessary, in targeting silvicultural treatments, such as weed control.

An interesting survey was undertaken by the Ontario Ministry of Natural Resources in the mid-1980s (Andison 1987, Ont. Min. Nat. Res., unpublished manuscript). The survey identified all plantation forests in the northern portion of the province and established sampling plots in a subsample representing different species and plantation ages. Jack pine plantations were generally successful in terms of meeting stocking and free-growing standards. Both black spruce and white spruce plantations, however, were less successful, and less than half of the areas studied met both stocking and free-growing standards for coniferous forests. White spruce was identified as a particular problem as plantations were virtually indistinguishable from unplanted forests and, due to invasion of hardwood species, had growth below the poorest published yield tables for fully stocked spruce plantations. These results may be more of a historical record than an indication of the potential of current plantation programs, however. Rapid expansion of plantation forestry over the past decade has been accompanied by an increased awareness of the importance of vegetation management, and the success rate of reforestation programs is improving steadily.

Issues in Timber Production

A survey was conducted of growth rates in natural and managed stands across the country. The provincial and industrial agencies contacted reported substantial increases in growth rates in managed stands as opposed to natural stands of the same forest cover type (Appendix 1). Growth rates, in terms of wood volume, ranged from 0 to 8 $m^3 \bullet ha^{-1} \bullet year^{-1}$ in natural stands and from 3 to 16 $m^3 \bullet ha^{-1} \bullet year^{-1}$ in managed stands. The most productive regions of Canada appear to be the Great Lakes - St. Lawrence forest region and the coastal forest of southwestern British Columbia. Where interspecies comparisons have been made, pine species are almost always more productive than associated spruces. Data from intensively managed hardwood forests are rare, but seem close to the growth of conifers on similar sites in southern Ontario.

Estimates of forest growth in Canada are continually improving thanks to the passage of time, the increased sophistication of local agencies in yield estimation, and the increased numbers of permanent sample plots being studied. Compared with growth rates in other regions of the world, Canada does not appear to be a favourable place to grow trees as crops (Appendix 2). Hardwood plantations grow between 11 and 70 $m^3 \bullet ha^{-1} \bullet year^{-1}$ in tropical and Mediterranean regions and tropical pines produce between 7 and 30 $m^3 \bullet ha^{-1} \bullet year^{-1}$. These tropical plantations cost up to $2000 per hectare to establish, however, and the land base is under constant pressure. Another major issue is the degree to which we will have quality advantages over these fast grown tropical and subtropical woods. Radiata pine, for example, despite being grown as clear lumber, has a far coarser grain than Canadian pines. Pines from southern United States are known for having problems with nailability and internal stresses in the wood. Therefore, even though international competitors can outgrow Canadian forests on a hectare by hectare basis, the use of efficient management systems, including natural regeneration, can ensure Canadians a competitive, high quality resource into the future.

Although managed stand growth estimates for Canada are encouraging, they must be kept in perspective. For example, it appears that over 3.5 million ha/year are killed or harvested in Canada, but only 10-15% of that area is managed (Kuhnke 1989). In addition, these growth plots often represent the fully stocked portions of areas, they do not include the net loss due to roads or site degradation, and they do not indicate the proportion of the area treated unsuccessfully. Thus, although some agencies are beginning to use a randomly allocated permanent sample plot program to monitor regeneration success and forest growth, these programs have not yet produced tangible results.

Although still not of great significance in a whole forest context, silviculture programs are increasing annually in Canada and tend to be concentrated on productive, easily accessible sites. Such sites, of course, are the most important for timber production. The great majority of silviculture activity to date has been involved in reforestation treatments, particularly site preparation, planting, and weed control. The emphasis on reforestation relates more to provincial regulation and public demand than to the economics of various silviculture activities. In some cases, reforestation treatments cost $2000 per hectare to produce a free-growing plantation, an investment that cannot be recouped on a 80-100 year rotation. There has been a debate in Canada about whether we should concentrate all silviculture dollars on the best, say, 10% of our forestland and do nothing on the rest or manage the entire forest extensively, concentrating on natural regeneration (Benson 1988). The latter option requires a concerted effort to modify harvesting practices to preserve advance regeneration or encourage natural regeneration. Whatever style of regeneration program is chosen, most commentators suggest the need for less provincial regulation of site-specific performance and more evaluation of the success of whole-forest management (Weetman 1986; Baskerville 1988; Brand 1989). One result of this type of thinking is that the use of juvenile spacing or precommercial thinning is growing in importance as a tool to manage the time until merchantability is reached in naturally established forests (Turtle 1989).

Monitoring and Predicting Forest Growth

For forest management planning, information is required on the current resource and its response to management. This information is most commonly collected from forest inventories combined with local volume tables and provides a static description of the timber resource. Although inventory techniques are still being developed, most work concentrates on increasing the efficiency of the estimates rather than on obtaining new types of information.

Obtaining information about growth and the response of the forest to management or changing environmental conditions is not as straightforward. Traditionally growth predictions consisted of projecting the current inventory into the future based on historical growth rates. An underlying assumption of this approach is that future conditions controlling tree growth will not seriously differ from those of the past. This classical approach to growth and yield estimation requires periodic remeasurement of forest stands with permanent sample plots (PSPs) or reconstruction of stand development through stem analysis.

As changes in the environment and in forest management practices are accelerating, "new" stands are being created that have no historical equivalents. This has led to the development of growth models based on the current understanding of and, in some cases, best guesses related to the biological relationships determining forest development. By combining environmental variables and plant growth analysis with management scenarios, growth of these "new" stands can be predicted. Extrapolation from small experiments and trials to a large-scale resource and to new growth conditions provides a best guess of stand development with unknown precision and accuracy.

Historical Development of Growth and Yield Estimation

Originally, predicting the growth and yield of forests was based on field experience and local knowledge. However, increasing public concern about the management of the forest resource and the large areas currently under management agreements has led to a search for more objective methods to estimate growth and yield. These quantifiable growth and yield models also have the potential to be linked with models of insect infestations or silvicultural planning and to be used in decision support systems.

Yield tables (both normal and average density) have been developed for various regions of Canada (e.g., Plonski 1960; Johnstone 1977). These were usually for single species, and even-aged, normal, or average density, stands. They were constructed from temporary sample plot (TSP) and stem analysis data. Site classes were used to account for variations in soil conditions. Equations for many of these yield tables have been estimated, first using polynomial and later nonlinear relationships between yield and stand age (Payandeh 1974). Variable density yield tables have been developed, particularly for use in predicting growth of plantations (e.g., MacKinney et al. 1937; Berry 1984, 1987). Again, these are usually for even-aged monocultures, but they often use site index (height at some reference age) to account for site differences.

Recently, some simulation models have been developed or modified for use in Canada. These models vary widely in terms of resolution and ability to reflect changes in various conditions, as well as the calibration data required. These are generally computer-based models and can potentially handle complex species, age, and density combinations as well as management options. TASS (tree and stand simulator) (Mitchell 1975) grows individual trees, keeping track of branch dimensions to estimate wood quality. FORCYTE (Kimmins et al. 1988) is a nutrient cycling model that can incorporate species mixtures as well as understory vegetation, and models the nutritional status of forest stands. XENO, developed by MacMillan Bloedel, predicts individual tree growth on a plot that expands as the trees grow larger. All three models are currently being used for forest management decision making.

These models and others (Barclay and Hall 1986; Magnussen and Brand 1989) consist of a mixture of empirical and biological relationships. They can model a wide array of stand conditions and be linked to geographic information systems (GISs) to automate much of the work involved in management planning via looking up tables. Regeneration models are also being developed to model the growth of very young stands (Belli 1988). Early height growth has been used to link young stands with growth and yield models (Alban 1979; Thrower 1987).

Current Uses of Growth and Yield Models

A wealth of growth modelling techniques has been described (Ek et al. 1988; Boughton and Samoil 1990), but few are being used operationally. Models need to be calibrated for local conditions with local data and this frequently limits their application. Models developed as research or teaching tools often require extensive testing and modification prior to being used in operational planning. Individual tree models may contain too much detail and resolution to be practical for predicting stand level growth. As well, models are becoming more sophisticated in terms of the equipment and operator expertise required to use them. Finally, leading edge technologies usually undergo a trial period during which they are used alongside older machines and methods. Models are seldom used to their full potential immediately.

The following discussion outlines current methods of growth and yield forecasting used by a few Canadian companies and agencies.

Ontario Ministry of Natural Resources, Forest Resources Group

Since 1980, the province of Ontario has been negotiating forest management agreements (FMAs) with companies holding timber licences over large areas. These agreements make the companies responsible for forest management on their licence area as well as for calculating their maximum allowable cut. The latter is usually derived from inventory data provided by the province, augmented with company-conducted operational cruise information and information from Plonski's (1960) yield tables. The ministry has identified the lack of available growth and yield data as a major weakness in forest management planning and has drafted a plan to address this problem. The major needs are establishing PSPs for long-term data collection and, in the short term, working with available data and calibrating models from external sources. New models are required for natural stands of varying densities (Bell et al. 1990) and for second growth stands. Operational cruise guidelines are also being revised.

British Columbia Ministry of Forests, Inventory Branch

For natural stands, the British Columbia Ministry of Forests uses government- and industry-supplied inventory information with empirical variable density yield functions. These yield functions are derived locally from a combination of TSP and PSP data. The research branch has developed the TASS model for silvicultural planning and has used its results to project growth of managed stands of coastal Douglas fir (Mitchell and Cameron 1985) and interior lodgepole pine (Goudie et al. 1990).

New Brunswick Department of Forestry, Mines, and Energy

New Brunswick uses the provincial inventory combined with variable density empirical yield tables for management planning. Plans have been made to develop new growth and yield models for the next series of management planning reviews in 1992 and to include more biological and initial stand condition information than is currently covered in the TSP and PSP systems.

Ministère de l'Énergie et des Ressources du Québec

The province of Quebec uses yield tables combined with forest inventory data for forest management planning. Boudoux's (1978) empirical yield tables for the major coniferous species have been augmented with variable density yield tables for sugar maple, aspen, and white birch. All tables are based on TSP data or PSP data treated as TSP data (only one measurement used). A black spruce growth model is being prepared that uses differential equations and PSP data to predict growth and yield. The resulting tables will then be used by SYLVA, a forest management planning model, to predict the outcome of different management scenarios.

Weldwood of Canada Ltd. (Hinton, Alberta)

In the past at Weldwood, locally developed yield tables based on fire-origin natural stands were used for forecasting stand growth. However, growth plots indicate that these tables seriously underestimate growth following harvest (Udell and Dempster 1986). The company is currently calibrating the TASS model (Mitchell 1975) for growth of pine and spruce on the east slope of the Rocky Mountains and the SPS model (Arnie 1972) for mixed species forests (conifer-conifer and conifer-hardwood). Weldood plans to produce yield tables linked with a GIS and to "game" various management scenarios for specific areas. The company was able to undertake the calibration effort due to consistent maintenance of a PSP program initiated in the late 1950s. The PSP program currently consists of more than 3300 plots.

MacMillan Bloedel (Nanaimo, British Columbia)

Mr. S. Northway has developed a single-tree, distance-dependent model (XENO) that is calibrated for all commercial species within MacMillan Bloedel's limits. It is currently being used for forest management planning (using the curves output from computer runs) and has been approved by the British Columbia Ministry of Forests. XENO's limitations are that it carries a lot of detail not necessary for operational planning and does not include understory vegetation development (deer browse is an important planning consideration). Another model is currently under development to address some of these limitations. The new model will be linked with a GIS. Regeneration models are also being developed to model forest development from 0 to 20 years after harvesting.

Corner Brook Pulp and Paper Ltd. (Corner Brook, Newfoundland)

This company uses the FORMAN model for management planning. Growth predictions are based on empirical yield tables linked to a province-wide GIS. Currently, the major effort is being directed toward obtaining empirical data to validate yield information by measuring current stands and establishing plantation trials. Second growth stands are not yet old enough to produce reliable yield data and past growth is heavily influenced by historic spruce budworm epidemics.

Future Issues in the Regeneration and Growth of Canadian Forests

Major issues relating to forest regeneration and growth can be grouped in three categories: information, environment, and management. There is a continuous demand for better information on the effect of harvesting on regeneration, the effect of silviculture on the growth of forests, and on the development of stands of a certain density and species composition on a given site type. There is also a need for more statistically valid information on the average success rate of our regeneration programs, the growth of forests after fire, harvesting, insect epidemics, and the productive forest land base. This information is necessary to evaluate forest policy alternatives (e.g., intensive versus extensive management), to choose harvesting systems, to design silviculture programs, and, most importantly, to enable public reporting of the human impact on the forest.

Issues related to the environment include climatic change, atmospheric pollutants, and forest management activities. There is still a great deal of uncertainty about if and to what extent the climate will change during the next 50 years. Nevertheless, if the average predictions occur, the Canadian forest landscape will be radically redrawn. Both radiation and water balance will be changed and will affect disturbance and species distribution as mentioned earlier. In light of this potential catastrophe, all growth predictions must be viewed with uncertainty. Atmospheric pollutants are also a potential threat to forest growth, and there is adequate supporting evidence in this regard from Europe (Schulze 1989). The degree to which the recent maple decline in eastern Canada can be attributed to pollution is still uncertain, but a long-term plot network has been established to monitor this situation (D'Eon and Power 1989). Finally, the increasing environmental awareness of the public and the growing concern over sustainable development of Canada's timber resources have made questions on old-growth forest preservation, genetic conservation, and ecological diversity public topics for the first time. The whole context and the objectives of previous forest management have been questioned (Franklin 1989; M'Gonigle 1989) and goals of plantation establishment and timber production are being reviewed in terms of their effect on the whole forest landscape.

Recommendations

1. Continued research is needed on the factors controlling regeneration, distribution, and growth of Canadian forests from a biological perspective. More use of bench mark test sites and uniform experimental designs would allow elucidation of the interrelationships among climate, environmental conditions, and tree productivity.
2. Permanent sample plot programs designed to indicate actual regeneration, species composition, and growth of the forest are necessary. These plots should indicate natural forest dynamics, response to disturbance, and response to silvicultural treatments for the major regions of the country. The PSPs would largely be for regional use, but may also provide some national statistics for the public.
3. The next generation of growth and yield models must be made biologically meaningful if a realistic evaluation of forest growth under nonhistorical conditions is to be expected. The multiplicity of approaches to process modelling is a problem in that a coordinated effort will be required to build these models. These new models should address the dynamics of forest growth, water yield, and wildlife habitat. They should be usable at a stand level and at a landscape-process level (e.g., whole drainage models).
4. Major new initiatives, such as those suggested above, cannot be successfully implemented by a number of agencies working in isolation. Coordinated data collection, experimentation, and process model development require both cooperation and coordination. The current Canadian Forest Inventory Committee has been useful in setting out cooperative or standardized approaches to forest inventorying. A similar body, charged with sharing growth and yield information and approaches, would be a valuable organization in Canada.

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Appendix 1. Survey of Canadian mean annual increments in timber volume by forest region

				Maximum Mean Annual Increment in Volume		
Forest Region①	Species	Spacing or Density	Site Index or Quality②	Natural Stands	Plantation	Comments
B.C. coast	75 % western hemlock type		24 m	5.3 m^3/ha③		Natural stands④
		600/ha	24 m		6.9 m^3/ha③	Minimum silviculture, meeting MoF standards. Prescribe burn and plant on areas with low natural regeneration, brushing on medium and high sites
		1200/ha	24 m		7.9 m^3/ha③	Basic silviculture, some broadcast burning, site prep., brushing, planting, and spacing. 1.6 times more silvicultural dollars than minimum silviculture
		1500/ha	24 m		8.3 m^3/ha③	Basic silviculture, brushing, spacing, higher planting densities. 2.4 times more silviculture dollars than minimum silviculture
	Douglas fir	2500/ha	25 m		5.9 m^3/ha⑤	Age of MAI culmination = 118 years (dbh limit 22.5 + cm) (Mitchell and Cameron 1985)
		2500/ha	40 m		15.3 m^3/ha⑤	61 years (ibid)
		1100/ha	25 m		6.1 m^3/ha⑤	110 years (ibid)
		1100/ha	40 m		15.0 m^3/ha⑤	59 years (ibid)
		4400/ha	25 m	6.1 m^3/ha⑤		110 years (ibid)
		4400/ha	40 m	16.1 m^3/ha⑤		67 years (ibid)
		4400/ha	25 m	5.8 m^3/ha⑤		111 years - precommercially thinned to 500 stems/ha (ibid)
		4400/ha	40 m	6.0 m^3/ha⑤		69 years - precommercially thinned to 500 stems/ha (ibid)
B.C. interior	Lodgepole pine	2500/ha	15 m		3.7 m^3/ha⑤	Age = 92 (Goudie et al. 1990)
		2500/ha	25 m		9.0 m^3/ha⑤	Age = 46 (ibid)

①Rowe's (1972) "Forest Regions of Canada"
②Site index at age 50 unless otherwise indicated
③Standing net volume to 10 cm top and 30 cm stump
④Pers. comm. [illegible]ick Smith, 1990. MacMillan Bloedel Limited, Woodlands Services Division
⑤Gross merchantable volume

Appendix 1 (con't)

				Maximum Mean Annual Increment in Volume		
Forest Region①	Species	Spacing or Density	Site Index or Quality②	Natural Stands	Plantation	Comments
Alberta boreal	Lodgepole pine	1100/ha	15 m		3.2 m^3/ha③	107 years (ibid)
		1100/ha	25 m		8.9 m^3/ha③	62 years (ibid)
		10 000/ha	15 m	3.4 m^3/ha③		86 years (ibid)
		10 000/ha	25 m	8.0 m^3/ha③		57 years (ibid)
		4400/ha	15 m	3.3 m^3/ha③		100 years (ibid)
		4400/ha	25 m	7.9 m^3/ha③		58 years (ibid)
			13 m	2.02 m^3/ha③		Fire origin growth (Udell and Dempster 1986)
			17.6 m	4.20 m^3/ha③		Early projections from harvested areas managed (mainly density control) (ibid)
Ontario, Great Lakes - St. Lawrence	Red pine	1.75 m 2.0 m 1.25 m	15 m 21 m 27 m		6.04 m^3/ha⑤ 9.72 m^3/ha⑤ 15.40 m^3/ha⑤	From yield tables (Berry 1984)
	Red pine		Average PNFI④	5.4 m^3/ha③		From inventory data (Bonner and Magnussen 1986)
	White spruce	2.0 m 2.0 m 1.25 m	15 m 21 m 24 m		4.18 m^3/ha⑤ 7.42 m^3/ha⑤ 10.82 m^3/ha⑤	From yield tables (Berry 1987)
	Spruce		Average PNFI	4.8 m^3/ha③		From inventory data (Bonner and Magnussen 1986)
	Aspen		Average PNFI	5.3 m^3/ha③		From PNFI records
	Jack pine				8.2 m^3/ha⑤	(Janas and Brand 1988)
			Average PNFI	6.2 m^3/ha⑤		
	Tolerant Hardwoods		Average PNFI	3-4 m^3/ha⑤ 2-6 m^3/ha⑤		From inventory data (Bonner and Magnussen 1986) From PNFI records

① Rowe's (1972) "Forest Regions of Canada"
② Site index at age 50 unless otherwise indicated
③ Gross merchantable volume
④ Petawawa National Forestry Institute
⑤ Gross total volume

Appendix 1 (con't)

				Maximum Mean Annual Increment in Volume		
Forest Region①	Species	Spacing or Density	Site Index or Quality②	Natural Stands	Plantation	Comments
Ontario, Great Lakes - St. Lawrence	Hybrid poplar	?	Good		6.92 m^3/ha⑤ range from 3.49 - 11.2 m^3/ha⑤	Age 12 years. Intensive weed control, ploughing and discing. Performance of better clones.
	Trembling aspen		Good	4.4 m^3/ha④		Age 20 years
Ontario boreal	Upland spruce	High	>12 m	2.86 m^3/ha④		Age 70 years (Whynot and Penner 1990)
	Black spruce	High	9-12 m	2.38 m^3/ha④		85 years (ibid)
	Black spruce	High	<9 m	2.39 m^3/ha④		112 years (ibid)
Quebec eastern boreal region	Black spruce	23.0 m^2/ha	12.2 m	2.10 m^3/ha③		60 years (Boudoux 1978)
		18.1 m^2/ha	9.1 m	1.41 m^3/ha③		70 years (ibid)
		11.2 m^2/ha	6.1 m	0.80 m^3/ha③		85 years (ibid)
Western boreal region		23.0 m^2/ha	12.2 m	2.13 m^3/ha③		65 years (ibid)
		17.0 m^2/ha	9.1 m	1.39 m^3/ha③		75 years (ibid)
		9.4 m^2/ha	6.1 m	0.71 m^3/ha③		95 years (ibid)
Quebec boreal region	Balsam fir	34.9 m^2/ha	15.2 m	3.3 m^3/ha③		35 years (ibid)
		34.2 m^2/ha	12.2 m	2.65 m^3/ha③		40 years (ibid)
		28.5 m^2/ha	9.1 m	1.75 m^3/ha③		50 years (ibid)
St.-Lawrence region		33.0 m^2/ha	15.2 m	3.45 m^3/ha③		40 years (ibid)

①Rowe's (1972) "Forest Regions of Canada"
②Site index at age 50 unless otherwise indicated
③Gross merchantable volume
④Gross total volume
⑤Pers. comm. Sylvia Strobl, Ont. Min. Nat. Res., gross merch. volume

Appendix 1 (con't)

				Maximum Mean Annual Increment in Volume		
Forest Region①	Species	Spacing or Density	Site Index or Quality②	Natural Stands	Plantation	Comments
Quebec	Jack pine	27.8 m^2/ha	12.2 m	2.57 m^3/ha③		40 years (ibid)
		24.6 m^2/ha④	15.2 m		2.33 m^3/ha③	60 years (Boudoux 1978)
		18.1 m^2/ha	12.2 m		1.56 m^3/ha③	65 years (ibid)
Quebec Great Lakes - St. Lawrence	Red pine	2.25 m⑤ normal*	3 m 15 years		5.48 m^3/ha③ 2.95	45 years (Bolhgari and Bertrand 1984) 45 years, 3441 stems/ha at age 15
		2.25 m normal	6 m 15 years		8.68 m^3/ha③ 5.89	45 years (ibid) 45 years, 2226 stems/ha at age 15
		2.25 m normal	8m 15 years		11.19 m^3/ha③ 8.25	45 years (ibid) 45 years, 1884 stems/ha at age 15
	Jack pine	2.25 m normal	3 m 15 years		2.68 m^3/ha③ 1.60	40 years (ibid) 40 years, 4184 stems/ha at age 15
		2.25 m normal	6 m 15 years		4.71 m^3/ha③ 3.64	40 years (ibid) 40 years, 2749 stems/ha at age 40
		2.25 m⑤ normal*	8 m 15 years		6.35 m^3/ha③ 5.24	40 years (Bolghari and Bertrand 1984) 40 years, 2359 stems/ha at age 15
	White pine	2.25 m normal	6 m 25 years		2.79 m^3/ha③ 5.27	40 years (ibid) 20 years, 22 195 stems/ha at age 15
		2.25 m normal	9 m 25 years		4.24 m^3/ha③ 7.93	40 years (ibid) 15 years, 4859 stems/ha at age 15
		2.25 m normal	12 m 25 years		6.09 m^3/ha③ 10.22	15 years (ibid) 15 years, 3279 stems/ha at age 15
	Scots pine	2.25 m normal	6 m 25 years		1.77 m^3/ha③ 1.92	45 years (ibid) 45 years, 4193 stems/ha at age 40

①Rowe's (1972) "Forest Regions of Canada"
②Site index at age 50 unless otherwise indicated
③Gross merchantable volume
④Basal area of stems 2.54 cm and larger at age 50
⑤Square spacing
*Full stocking (normal density)

Appendix 1 (con't)

				Maximum Mean Annual Increment in Volume		
Forest Region①	Species	Spacing or Density	Site Index or Quality②	Natural Stands	Plantation	Comments
		2.25 m④ normal*	10 m 25 years		3.77 m³/ha③ 4.16	35 years (ibid) 40 years, 2702 stems/ha at age 15
		2.25 m normal	14 m 25 years		5.73 m³/ha③ 6.56	25 years (ibid) 30 years, 2048 stems/ha at age 15
	White spruce	2.25 m④ normal	6 m 25 years		1.97 m³/ha③ 2.26	50 years (Bolghari and Bertrand 1984) 50 years, 4484 stems/ha at age 15
		2.25 m normal	9 m 25 years		3.98 m³/ha③ 4.65	50 years (ibid) 50 years, 3740 stems/ha at age 15
		2.25 m normal	12 m 25 years		6.04 m³/ha③ 7.69	50 years (ibid) 50 years, 3263 stems/ha at age 40
	Norway spruce	2.25 m normal	6 m 25 years		3.82 m³/ha③ 3.60	55 years (ibid) 60 years, 4720 stems/ha at age 15
		2.25 m normal	10 m 25 years		6.49 m³/ha③ 6.81	50 years (ibid) 60 years, 3255 stems/ha at age 15
		2.25 m normal	14 m 25 years		9.93 m³/ha③ 11.05	45 years (ibid) 55 years, 2608 stems/ha at age 15
	Larch	2.25 m normal	8 m 25 years		1.43 m³/ha③ 4.25	35 years (ibid) 35 years, 7030 stems/ha at age 15
Quebec central to south	Larch	2.25 m④ normal	13 m 25 years		3.53 m³/ha③ 7.56	25 years (Bolghari and Bertrand 1984) 20 years, 4586 stems/ha at age 40
		2.25 m normal	18 m 25 years		6.80 m³/ha③ 11.58	20 years (ibid) 15 years, 3288 stems/ha at age 15
	European larch	2.25 m normal	10 m 25 years		2.70 m³/ha③ 10.98	35 years (ibid) 15 years, 10 676 stems/ha at age 15

①Rowe's (1972) "Forest Regions of Canada"
②Site index at age 50 unless otherwise indicated
③Gross merchantable volume
④Square spacing
*Full stocking (normal density)

Appendix 1 (con't)

				Maximum Mean Annual Increment in Volume		
Forest Region①	Species	Spacing or Density	Site Index or Quality②	Natural Stands	Plantation	Comments
		2.25 m⑤	15 m 25 years		5.63 m^3/ha③	35 years (ibid)
		normal*			14.70	15 years, 4949 stems/ha at age 15
		2.25 m	20 m 25 years		9.48 m^3/ha③	30 years (ibid)
		normal			17.83	15 years, 3096 stems/ha at age 40
New Brunswick	Jack pine	1900/ha	Medium to good		8.2 m^3/ha④	29 years 15.5 m dominant height
		2300/ha	Medium to good		8.7 m^3/ha④	29 years 15.5 m
Acadian	Black spruce	1950/ha	Medium		5.4 m^3/ha④	34 years 13.0 m
	White spruce	1800/ha	Medium		5.5 m^3/ha④	34 years 13.0 m
New Brunswick Great Lakes - St. Lawrence	Black spruce	3700/ha			6.4 m^3/ha④	22 years 9.2 m
		4100/ha			6.6 m^3/ha④	22 years 9.2 m
		5800/ha			5.6 m^3/ha④	21 years 7.6 m
		5000/ha			5.4 m^3/ha④	21 years 8.6 m
	White spruce	3200/ha			7.0 m^3/ha④	23 years 9.8 m
		3500/ha			3.3 m^3/ha④	24 years 8.6 m
		3600/ha			8.1 m^3/ha④	22 years 10.0 m
		3600/ha			4.6 m^3/ha④	22 years 9.4 m
Newfoundland	Balsam fir			1.85 m^3/ha④		Old growth
			Good	3.36 m^3/ha④		Managed (mainly density control)
			Medium	2.24 m^3/ha④		Managed (mainly density control)
Yukon boreal	Lodgepole	2551/ha		2.2 m^3/ha④		Regeneration following clearing 28 years, 10.4 m tall (Bonner 1989)
	White spruce	239/ha		-		
	Black spruce	470/ha		-		
	Hardwoods	204/ha		-		
	Total	3464/ha		2.2 m^3/ha④		
	Lodgepole	853/ha		1.3 m^3/ha④		Partially cut area 36 years, 10 m tall (ibid)
	White Spruce	255/ha		-		
	Black Spruce	1100/ha		0.5 m^3/ha④		
	Hardwoods	487/ha		0.3 m^3/ha④		
	Total	2694/ha		2.2 m^3/ha④		

①Rowe's (1972) "Forest Regions of Canada"
②Site index at age 50 unless otherwise indicated
③Gross merchantable volume
④Gross total volume
⑤Square spacing
*Full stocking (normal density)

Appendix 1 (con't)

				Maximum Mean Annual Increment in Volume		
Forest Region①	**Species**	**Spacing or Density**	**Site Index or Quality**②	**Natural Stands**	**Plantation**	**Comments**
	Lodgepole	576/ha		0.9 m³/ha③		Undisturbed, natural forest 112 years 13.4 m tall (ibid)
	White spruce	37/ha		1.2 m³/ha③		
	Black spruce	993/ha		-0.2 m³/ha③		
	Hardwoods	267/ha		-		
	Total	1872/ha		2.0 m³/ha③		

①Rowe's (1972) "Forest Regions of Canada"
②Site index at age 50 unless otherwise indicated
③Gross total volume

Appendix 2. Growth rates of the world's forests

Country	Species	Maximum MAI (m^3/ha)-rotation	Data source
BOREAL REGION			
Canada		1.645	
– Acadian	60% coniferous	1.53	Lowe[1]
– B.C. coast	95% coniferous	2.53	Lowe
– Boreal	63% coniferous	1.65	Lowe
– Boreal barren	84% coniferous	0.44	Lowe
– Boreal grassland	85% coniferous	1.43	Lowe
– Columbian	95% coniferous	2.05	Lowe
– Deciduous	80% deciduous	2.08	Lowe
– Great Lakes - St. Lawrence	62% deciduous	1.85	Lowe
– Montane	93% coniferous	1.78	Lowe
– Subalpine	94% coniferous	2 09	Lowe
Denmark		*5.1*	
Finland	Hardwood	5	WFR[2]
		3.0	Jaako
Norway		*1.9*	*WFR*
Sweden	Pine	5-12	WFR
		3.3	ANDB
USSR - Siberia	*Conifer*	*1 - 1.5*	*WFR*
			World
TEMPERATE REGION			
Australia	Hardwood	0.6	WFR
	Coniferous	20	Jaako
– N.S. Wales	Coniferous	15	R. Wilson
– Victoria	Coniferous	17.5	R. Wilson
Austria		*6.0*	*WFR*
Belgium		4.4	WFR
Bulgaria		*2.2*	*WFR*
Chile/New Zealand	*Pinus radiata*	Avg. 20 range 15-30	Jaako
Cyprus	*Pinus & Quercus*	*0.75*	*WFR*
		0.5	WFR
Czechoslovakia		3.5	WFR
France		*3.7*	*WFR*
Germany, Dem. Rep.		4.9	WFR
Germany, Fed. Rep.		*5.5*	*WFR*
Great Britain		4.5	WFR
Greece		*2.2*	*WFR*
Hungary		5.4	WFR
Ireland		*3.2*	*WFR*
Israel		2.5	WFR
Italy		*2.1*	*WFR*
Japan		3.1	WFR
Korea		*0.24*	*WFR*
Luxembourg		3.2	WFR
Netherlands		*4.8*	*WFR*
New Zealand		15.3	WFR

[1] J. Lowe, PNFI, Can. Forest Resource Data System
[2] Persson, R. 1974

Appendix 2 (con't)

Country	**Species**	**Maximum MAI (m^3/ha)-rotation**	**Data Source**
Poland		*2.8*	*WFR*
Portugal	Hardwood	11	Jaako
		2.8	WFR
Romania		*4.3*	WFR
South Africa		12.2	WFR
Spain		*1.2*	*ANDB*
Switzerland		4.7	WFR
Turkey		*0.9*	*WFR*
U.S.		3.1	WFR
– PNW	Hybrid poplar	20-70	ANDB
– south	Southern pine	7-14	ANDB
Yugoslavia		*3.2*	*WFR*
TROPICAL REGION			
Aracruz	*Hardwood*	*Avg. 70, max 110*	*ANDB*
Australia - Tasmania	*Eucalyptus nitans*	9.5	FAFPIC
– N.S. Wales	*E. grandis*	7.2	FAFPIC
– Victoria	*E. nitans/E. grandis*	17.8	FAFPIC
Brazil	Unexploited *Araucaria*	*2.13*	*WFR*
	Exploited *Araucaria*	*0.97*	*WFR*
Brazil/Argentina	Hardwood	25	WFR
Chile/New Zealand	*Pinus radiata*	*Avg. 20 range 15-30*	*Boulter*
Indonesia	Hardwood	12-40	WFR
Jamaica	*Pinus patula*	*11*	*WFR*
	P. caribaea	*11*	*WFR*
	Eucalyptus salgna	*9*	*WFR*

An Approach to Increasing Sustainable Yields in Nova Scotia

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Abstract

Nova Scotia's forest industry makes an important contribution to the provincial economy, yet estimates indicate that there is considerable potential for expanding timber production through improved forest management. A Royal Commission in the mid-1980s led the Government of Nova Scotia to a new forest policy in 1986 that included the goal of doubling forest production by the year 2025. The silviculture requirements of such a plan include expanded precommercial thinning programs, more planting, and increased use of commercial thinning. This will result not only in an increase in production per hectare, but also in a younger, more balanced forest. One of the key aspects of increasing the yield of timber from Nova Scotia's forests is the participation of private landowners, who control 73% of the forestland. Governments have made successful efforts to assist private landowners in managing their lands more effectively, and these programs will continue in the future.

Résumé

La contribution de l'industrie forestière de la Nouvelle-Écosse à l'économie provinciale est importante; pourtant, les estimations révèlent que l'amélioration de l'aménagement forestier pourrait augmenter énormément la production forestière. Les conclusions d'une Commission royale d'enquête, au milieu des années 80, a poussé le gouvernement de la Nouvelle-Écosse à adopter en 1986 une nouvelle politique sur les forêts qui prévoit notamment que la production forestière doublera d'ici 2025. Parmi les exigences sylvicoles d'un tel plan, mentionnons l'élargissement des programmes d'éclaircie pré-commerciale, l'intensification du reboisement et l'utilisation accrue de l'éclaircie commerciale. Ces interventions se traduiront par une augmentation de la production à l'hectare et également par l'apparition d'une forêt plus jeune et plus équilibrée. L'une des principaux aspects de l'accroissement du rendement des forêts de la Nouvelle-Écosse est la participation des propriétaires de boisés privés qui possèdent 73 % des terrains forestiers. Les gouvernements ont réussi, grâce aux efforts qu'ils ont déployés, à aider les propriétaires de boisés privés à aménager leurs terres de façon plus efficace et ces programmes se poursuivront dans l'avenir.

Background

Nova Scotia, Canada's second smallest province, contains approximately 1.3% of Canada's forestland, but supplies 2.4% of the nation's annual roundwood harvest.

Unlike most other Canadian provinces, most of Nova Scotia's forestland is privately owned (73%). Roughly half of the province's 4.1 million ha of productive forestland is controlled by 30 000 small woodlot owners, each owning 400 ha or less. Because these lands are among the most productive and accessible in the province, policies designed to increase quality and the level of harvests must encourage active participation by this sector.

In 1988, approximately 4.3 million m^3 (1.9 million cords) of wood were harvested with a manufactured value of $850 000 000. Employment (person-years) generated by the industry was estimated at 11 000 direct and 22 000 indirect jobs.

Although these are significant benefits, the forests of Nova Scotia are only yielding a fraction of what they could yield. Analysis of recent forest inventory data indicates that the average hectare of forestland on mainland Nova Scotia is yielding, at maturity, only one fifth to one sixth of its potential, i.e., 1.47 $m^3 \bullet ha^{-1} \bullet year^{-1}$ compared with a potential of 8.4 $m^3 \bullet ha^{-1} \bullet year^{-1}$. Why? There are two primary reasons for this shortfall: low stocking and a high rate of mortality resulting from a lack of forest management in the past. Low stocking is attributed to past high-grading of stands for sawlogs and failure to replant extensive areas burned by wildfires in the early 1900s. High mortality results from the largely overmature forest (Figure 1). Each year, 2.7 million m^3, equivalent to 63% of the industrial harvest, dies. The problem of low productivity was further exacerbated by the spruce budworm epidemic, beginning

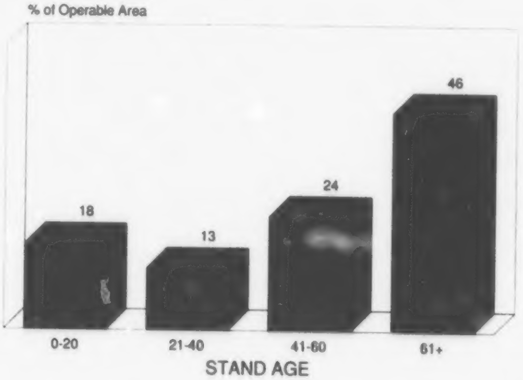

Figure 1. Age class distribution for the operable forest area in Nova Scotia, 1990.

in the mid-1970s, which resulted in a substantial reduction of the softwood growing stock on Cape Breton Island and the northern mainland.

Development of Sustainable Harvest Computer Models

The problem of low productivity precipitated the development of a computer forest simulation model, the latest version of which is called SAWS (Strategic Analysis - Wood Supply). Prior to 1974, the annual allowable cut (AAC) in Nova Scotia had been calculated using simple mathematical formulas, such as dividing the gross merchantable volume by half the rotation age. Output from the SAWS model is used to guide the government in decisions regarding the forest management program needed to achieve increasing sustainable harvest goals given various constraints, including woodlot owner participation, deductions for cull and waste, inaccessibility, and maximum tolerated losses due to abnormal attacks by insects and diseases, etc.

During the Royal Commission hearings on forestry in the early to mid-1980s, results from the model were used to illustrate the effect on sustainable wood supplies of three different management scenarios (Anon. 1984):

1. eliminating all silvicultural programs
2. maintaining the silviculture program at its 1983 level
3. doubling the present silviculture program

The results were important in demonstrating to the Commissioners that the future wood supply (given an adequate protection program) is largely dependent on the intensity of silviculture practiced. For example, Figure 2 indicates that a decision to halt all silviculture would have reduced the softwood AAC by roughly one third. Alternatively, doubling the present level of silviculture would have increased the softwood supply immediately by 20%, rising to 66% by the year 2040.

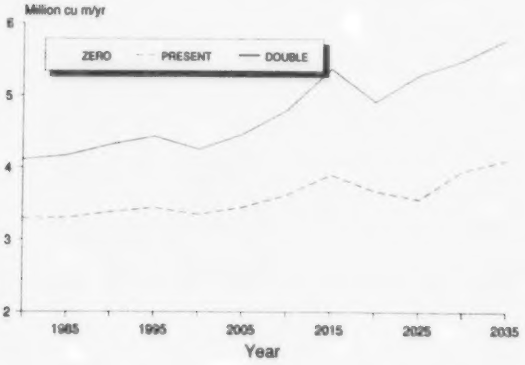

Figure 2. Effect of varying levels of silviculture investment on softwood supplies.

Doubling of Sustainable Yields by 2025

Two years following the Royal Commission Report (Anon. 1984), the Government of Nova Scotia issued a new forest policy (Anon. 1986). One of its goals was to double production by the year 2025. To determine what kind of management program was needed to achieve this goal, a demand curve was first constructed based on the expansion plans of existing industry, allowances for new industry, and the objective of doubling wood supplies by 2025. The SAWS model was then run several times to determine the minimum level of specifically chosen silvicultural treatments needed to achieve a matching supply curve. Graphical output from the first runs was extremely useful in helping to determine the timing of and increases in various silviculture treatments needed to overcome supply shortfalls. For example, Figure 3 indicates that the number of acres to be cleaned (precommercially thinned) was less than the number available; hence, the number could be increased to offset wood shortages.

Silviculture Program

The three most important silviculture treatments required to double production were planting, cleaning, and commercial thinning. These treatments were selected not only to help restore productivity but also to increase the quality, diversity, and vigour of the forest.

Planting

Planting contributes to the goal of doubling production in three ways:

1. Increasing productivity: The expected yield from plantations on average sites in Nova Scotia, assuming 70% stocking at a rotation age of 40 years, is 179 m^3/ha compared with present average yields from mature unmanaged forests of 88 m^3/ha at age 60. Planting, therefore, increases average

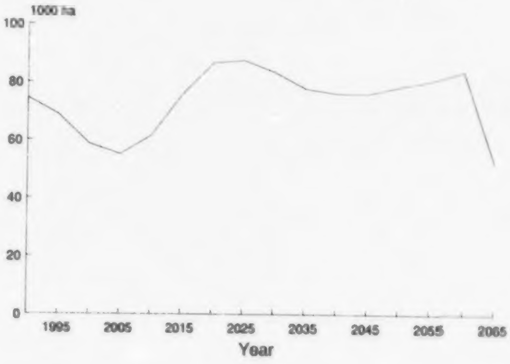

Figure 3. Example of an area report for cleaning.

productivity, expressed in terms of mean annual increment, by approximately 200%.

2. Reducing the rotation age: Plantations mature 20 years earlier (i.e., age 40) than natural unmanaged stands. Therefore, plantations increase productivity by permitting a larger area and hence a larger volume of forest to be cut during the next 40 years - the period of critical supply.
3. Reducing mortality: Future losses to insects, diseases, and other injurious agents are projected to be considerably less because of the more balanced age class distribution and younger, healthier forest resulting primarily from the increased harvesting, planting, and cleaning programs.

Cleaning (Premerchantable and Thinning)

In Nova Scotia, cleaning is defined as a premerchantable spacing operation in naturally regenerated stands ranging from 1.5 to 9 m in height. Although both cleaned and planted stands mature at an age of 40 years on average sites, cleanings have the advantage that they are cheaper and mature 25 years after treatment rather than 40. This treatment, therefore, is crucial to ensuring that the wood needed during the early stages of the critical supply period (i.e., 2015 to 2030) will be available. To ensure that cleanings and plantings will be ready for harvest when needed, spacing guidelines are designed to ensure that treated stands reach peak mean annual increment (MAI) by age 40. For example, Figure 4 indicates that for sites rated at LC8 (i.e., potentially capable of producing a maximum of 8 $m^3 \bullet ha^{-1} \bullet year^{-1}$), acceptable spacing for harvesting by age 40 can range up to 3.0 m x 3.0 m, whereas for LC6 sites, spacing cannot exceed 2.0 m x 2.0 m.

Commercial Thinning

Commercial thinning, defined as a spacing operation in stands greater than 14 cm in diameter, helps achieve the goal of doubling forest productivity by

1. Increasing productivity: Nova Scotia's variable density growth and yield model indicates that thinning can increase MAI and, therefore, production over a 60 year rotation by 25 to 30%. Increased production is primarily a function of harvesting trees that have died or would have died during the 10 to 20 year period between thinning and harvesting. Together with the increased harvesting program, thinning is one of the main treatments that will immediately reduce mortality losses.
2. Increasing sawtimber supplies: Because thinning operations harvest the poor quality and smaller trees, almost all trees harvested during the final cut will be of sawlog quality. This treatment, therefore, helps ensure that there will be an increasing supply of sawlogs in the future.
3. Increasing resistance to injurious agents: Although thinned stands will generally have increased resistance to most injurious agents, resistance to wind damage can actually be decreased. Selection of stands for thinning, therefore, is crucial. Experience indicates that the risk of wind damage can be minimized by restricting thinning operations to deep, well-drained, moderately exposed - sheltered sites where crop trees have a crown to stem ratio greater than 1:3 (Anon. 1988).

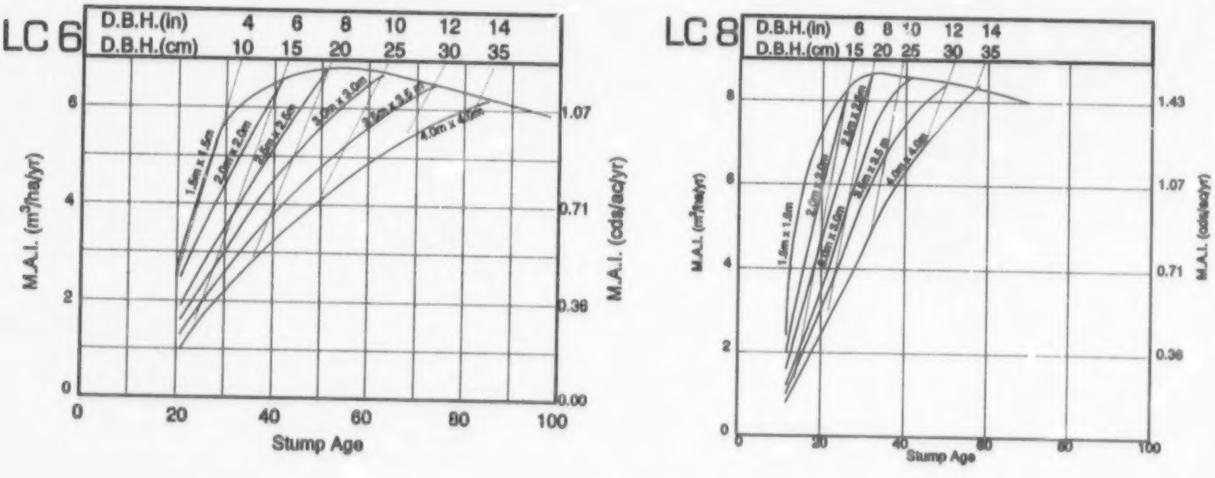

Figure 4. Effect of initial spacing and site quality on rotation ages (based on peak MAI) for planted and cleaned stands.

Wildlife-Timber Management Interface

To ensure that timber production activities do not negatively affect wildlife populations, the Nova Scotia government issued a wildlife policy in 1987 (Anon. 1987). Two years later, in 1989, the Department of Lands and Forests issued a set of wildlife guidelines that provided for greenbelts along streams, wildlife corridors, maximum clear-cut sizes, machine exclusion zones, cavity trees, etc. (Anon. 1989). Although these guidelines are mandatory only on Crown land, they are generally adhered to by the pulp and paper companies and woodlot owners participating in federal-provincial forestry assistance programs. Newly researched techniques capable of further improving wildlife resources, including fish, will be incorporated into future revisions of the guidelines.

The Future Forest

The silviculture and increased harvesting program required to double production will have a dramatic effect on the future forest. For example, yields from softwood stands harvested on woodlots will increase from 101 m^3/ha in 1990 to 140 m^3/ha in 2065 - a 39% increase (Figure 5).

The more rapid rate of harvesting coupled with shorter rotations of plantations and cleaned stands results in a younger forest and creates a considerably more balanced age class distribution (Figure 6). This means that the future forest should be much more vigorous and healthy, lower in height and, therefore, less prone to damage by windstorms, and less susceptible to insect and disease damage due to its younger age and greater vigour.

The younger forest and more balanced age class distribution will also result in a dramatic decrease in the volume of wood in stands eligible for harvesting at any time (Figure 7). This will likely translate into higher roadside prices because of reduced supply choices.

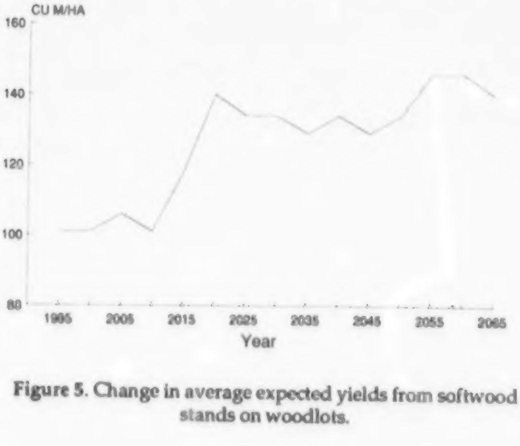

Figure 5. Change in average expected yields from softwood stands on woodlots.

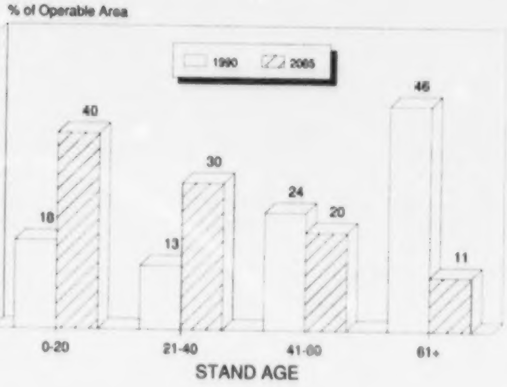

Figure 6. Change in age class distribution for operable forest areas, 1990 versus 2065.

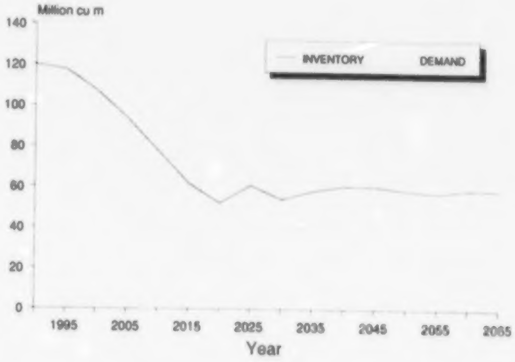

Figure 7. Change in the volume of softwood available for harvest versus annual demand.

One forest characteristic that remains unchanged is the cover type distribution. The proportion of area occupied by softwood stands, hardwood stands, and mixed wood stands will remain at traditional levels (Figures 8 and 9). The lower softwood and higher hardwood percentages for 1990 were caused by a drastic reduction in the softwood component of the forests of Cape Breton between 1975 and 1985.

Future Developments

With increasing competition in world markets, cost-effective ways to increase forest productivity will become a priority. From my perspective, expanding the commercial thinning program offers one of the most economically attractive and environmentally acceptable ways of substantially and immediately increasing productivity. This has long been recognized in other countries, such as Sweden, where commercial thinnings provide 30% of the annual harvest. In eastern Canada, thinning has not

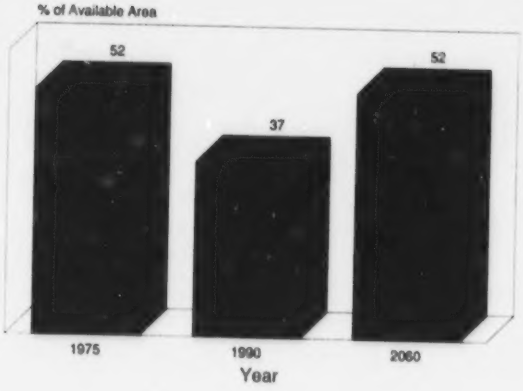

Figure 8. Change in area occupied by softwood stands.

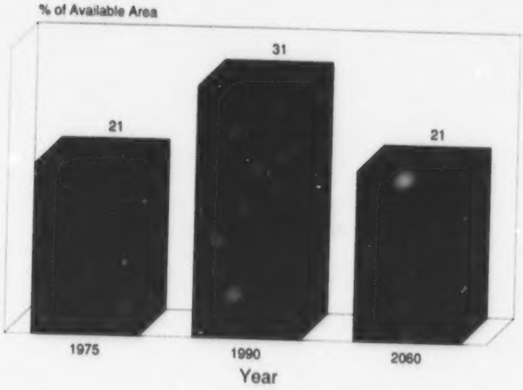

Figure 9. Change in area occupied by hardwood stands.

been practiced extensively perhaps because of the high cost of traditional motor-manual methods (up to $965 per hectare in Nova Scotia). However, thinning trials with recently introduced mechanical harvestors indicate that costs can be reduced considerably.

The same machines could be used to conduct shelterwood operations, resulting in substantially reduced regeneration costs by eliminating the need for planting. With regard to shelterwoods, further research is needed to better define the site-specific methods needed to achieve optimum conditions for germination and early growth of the desired species.

Introduction and expansion of exotic species plantings offer another way of substantially increasing productivity. For example, a recently completed study of 23 stands of Norway spruce ranging up to 60 years of age, indicates that this species is capable of outproducing native species by an average of 58% (Anon. 1989). Further studies on the more promising exotics need to be undertaken.

Finally, the new forest policy recognizes that woodlot owners are the key to achieving the province's forest management goals. The government is convinced, as expressed in the policy, that incentives rather than punitive taxation and/or legislation is the best approach to encouraging good forest management on these lands. To this end, Forestry Canada and the Nova Scotia government have entered into agreements to encourage and financially assist private landowners to manage their lands more effectively. This approach has worked well. To date, about 7000 of the 30 000 woodlot owners have had management plans prepared for their properties. These or similar programs must continue in the future if the goals of the forest and wildlife policies are to be achieved.

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Forecasting the Growth and Yield of Canada's Forests to 2050

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Abstract

Accurate predictions of the growth, biomass accruals, yields, and carbon balance of Canada's forests for the next tree crop rotation are needed rather urgently. Foresters must address the increasingly common allegation that Canada's forests are being overcut, and this requires a more accurate forecast of how our forests will accumulate harvestable biomass in the future. Society's growing concern about global warming and climatic change requires that an accurate carbon budget be prepared for Canada's forested landscapes. Preparation of such a budget requires accurate predictions of the net primary production of our forests, the allocation of production to harvestable and nonharvestable biomass, and the dynamics of organic matter in our forests under a variety of management strategies. Concerns about resource sustainability require growth and yield prediction systems that are sensitive to the impact of management and climatic change on long-term site productivity.

The forest growth and yield prediction systems commonly used in forestry do not provide an adequate basis for the predictions that are needed. "Historical bioassay" growth and yield models lack the flexibility to predict growth and yield under significantly altered management systems and environmental conditions. As experience-based prediction systems, they can only project into the future what we already know about growth and yield from the past. There is, therefore, an urgent need to combine these traditional prediction systems with sufficient ecological process simulation to give them the degree of prediction flexibility that is required by today's forest planners and policymakers.

This paper will briefly review the concepts of forest productivity, and the strengths and weaknesses of various growth and yield modelling approaches. The potential contribution of ecosystem management simulation models, such as FORECAST (FORestry and Environmental Change ASsessmenT) and FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator), to national forest growth and yield predictions is described, and a suggestion is made regarding how such models could be integrated with geographic information and forest inventory systems to provide an "ideal" modelling framework with which to address the issue of accruals to the timber capital and carbon storage of Canadian forests.

Résumé

Il est plutôt urgent d'établir des prévisions précises de la croissance, de l'accroissement de la biomasse, des rendements et du bilan du carbone des forêts du Canada au cours de la prochaine révolution des arbres. Les forestiers doivent pouvoir répondre aux allégations faites de plus en plus souvent au sujet de la surexploitation des forêts canadiennes. Or, la réponse exige qu'on soit en mesure de prédire avec précision la quantité de biomasse récoltable que s'accumulera dans nos forêts. Les préoccupations grandissantes de la société à l'égard du réchauffement global et du changement climatique rendront nécessaire l'établissement d'un bilan précis du carbone pour l'ensemble des terrains boisés du Canada. La préparation d'un tel bilan nécessite des prévisions précises de la productivité primaire nette de nos forêts, de la part de la production attribuable à la biomasse récoltable et non récoltable et de la dynamique de la matière organique dans nos forêts dans le cadre de diverses stratégies d'aménagement. Les préoccupations à l'égard du développement durable de la ressource exigent des systèmes de prévision de la croissance et du rendement qui soient sensibles aux questions relatives aux incidences de l'aménagement et du changement climatique sur la productivité stationnelle à long terme.

Les systèmes de prévision de la croissance et du rendement des forêts actuellement utilisés en foresterie ne permettent pas d'établir les prévisions nécessaires. Les modèles sur la croissance et le rendement «biologiques historiques» n'ont pas la souplesse nécessaire pour prédire la croissance et le rendement observables dans le cadre de régimes d'aménagement et de conditions environnementales fortement modifiés. Puisque ces systèmes de prévision sont empiriques, ils ne peuvent que transposer dans l'avenir nos connaissances actuelles sur la croissance et les rendements antérieurs. Il est donc urgent de conjuguer ces systèmes de prévision traditionnels à des modèles de simulation adéquats de processus écologiques pour leur donner le degré de souplesse prévisionnel dont ont besoin nos planificateurs et nos décideurs contemporains.

Le présent article examine brièvement les concepts de productivité forestière et les points forts et faibles des diverses approches de modélisation de la croissance et du rendement. Il décrit le rôle que pourraient éventuellement jouer des modèles d'aménagement des écosystèmes comme le FORECAST (FORestry and Environmental Change ASsessmenT [Évaluation des

changements forestiers et environnementaux]) et le FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator [Cycle des éléments nutritifs en forêt et évaluateur de la tendance des rendements]) dans l'établissement de prévisions sur la croissance et le rendement des forêts nationales et formule une suggestion sur la façon dont ces modèles pourraient être intégrés à des SIG (Systèmes informatiques géographiques) et à des systèmes d'inventaire forestier afin d'obtenir un cadre de modélisation «idéale» permettant d'aborder la question de l'accroissement du capital forestier et de la capacité de stockage du carbone des forêts canadiennes.

Introduction

Forestry has evolved at various times and places over the past 3000 years. A feature of this periodic attempt to ensure continuing supplies of various goods and services from forested landscapes is that development has generally followed a common pattern. Unregulated exploitation created local shortages that led to exploitation of more remote forests. This often resulted in wars of conquest and contributed to the creation of empires, and it generally provided a short-term solution to the timber supply problem. History repeated itself, however, and overexploitation led to shortages in these new areas. Faced with no alternative, governments then passed laws and established regulations in the hope that these would ensure sustained local supplies of timber and other forest products. In most cases, these laws and regulations failed to achieve their sustained yield objectives because they did not reflect the spatial and temporal variability of forests.

Most of the historical attempts to develop forestry failed. They did not succeed in providing sustained yield. They did not evolve beyond the initial centralized, administrative, nonecological approach to forest management. The historical origins of modern forestry can be found in the solution to this failure: the development of ecologically sound silviculture in Europe several centuries ago. Forestry in Europe did not remain in this stage, however. Over the years, there was a transition from a preoccupation with providing a renewable supply of strategic and industrial timber to forestry that was socially as well as silviculturally and ecologically sound: forestry that satisfied a variety of local needs as well as serving larger, centralized demands. Until this final stage is reached, forestry has generally been preoccupied with timber production, and silviculture has been the major focus of foresters. Although in some areas forestry evolved from wildlife habitat management, or from the need to protect watersheds, in most cases nontimber resource values were added to a basic timber management framework that constituted the major raison d'être for forestry.

The historical development of forestry in Canada has followed much the same pattern: unregulated exploitation, followed by a centralized, administrative, nonecological stage. Because Canada is such a young country and because Canadian forestry developed so recently, the transition to the next stage has been very recent. Only over the past two decades has there been a significant and widespread shift into the silvicultural/ecological stage. Before the results of this transition could be seen, however, in terms of an overall improvement in the quality and success of forest management (this would probably have required up to 50 years), forestry has been precipitated by public pressure into the final stage - social forestry.

Perceiving the predictable and perhaps inevitable failures of early Canadian forestry, and not understanding the historical development sequence through which our forestry is passing, much of the Canadian public has dismissed current forestry practice as unacceptable, inappropriate, and ultimately destroying the environment. Increasing public concerns about the "greenhouse effect," clear-cutting, the loss of old growth and biological diversity, and various other environmental issues has put foresters on notice: either demonstrate that forestry is sustainable, or lose much of the publicly owned forestland base to other land uses, or have the methods by which Canadian forests are to be managed dictated by nonforesters.

Are we overharvesting our forests? There are many components to this deceptively simple but in reality very complex question. Our ability to make long-term projections about how our forests will grow and accumulate biomass at the stand level under a variety of different management strategies, and in the face of the widely predicted global climatic change, is certainly one of them. Unquestionably, the age-class structure of the forest, the spatial pattern of stands of different age and species composition across the landscape, and the balance between old growth and second growth are extremely important determinants of the future supply of timber in a forest. In the short run, these "whole-forest" attributes have a dominant influence on the supply of logs, the employment, and the capital created by forestry. In the longer term, the future age-class structure, species composition, and volume of the forest are all determined by the growth of individual stands as well as by the rate and pattern of harvesting. Forecasting the growth and yield of individual stands, therefore, is an important part of forecasting future forest yields and selecting a current rate of harvest that will satisfy sustained yield objectives.

The purpose of this paper is to review briefly the factors that determine the rate at which biomass accumulates in forest stands, and to consider the extent to which these factors are incorporated into our growth and yield predication tools. Having noted some shortcomings of traditional methods of forecasting "accruals to forest capital," a description will be provided on how ecosystem simulation models, such as

FORECAST (FORestry and Environmental Change ASsessmenT) and, to a much more limited extent, the earlier FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator), can be used to evaluate the accuracy of traditional prediction methods in the face of climatic change and the significantly altered silvicultural strategies that the public is demanding. The paper will conclude with a suggested structure of an "ideal" prediction framework with which to address the sustainable level at which Canada's timber resources can be harvested.

Production Ecology of Forests, or What Determines How Fast Our Forests Accumulate Harvestable Biomass?

Accumulation of harvestable biomass in a stand is the result of a variety of factors. Biomass is created by capturing solar energy and combining it with various nutrient elements to form complex, high energy molecules. The magnitude of this capture is determined, first and foremost, by the magnitude and efficiency of the plants' energy-capturing apparatus - the foliage. The leaf biomass or leaf area per hectare and its photosynthetic efficiency are the most important determinants of the net primary production of the ecosystem. The ultimate determinant of the economic productivity of a forest stand, therefore, is the presence of an adequate biomass of foliage of the desired crop trees adequately supplied with moisture and nutrients - the soil resources that determine both the foliage mass and its efficiency.

If most of the leaf area is noncrop species (the herbs and shrubs of early succession, or noncommercial tree species), economic yields will obviously be small, even if the ecosystem is undamaged and has a high net primary productivity. Much of the recent concern about the state of Canadian forestry that led to the Federal-Provincial Forest Resource Development Agreements was not simply the result of harvesting practices that had damaged the ecosystem's productive capacity. In most cases, it was due to the failure of foresters to establish an adequate leaf area of the desired tree crop species following harvesting (i.e., not sufficiently regenerated (NSR) conditions). Failure to reforest promptly does not necessarily imply ecosystem degradation, although if an area remains deforested for a prolonged period there can be a significant loss of nutrients, organic matter, and soil fauna and flora from the site. More often, it simply means that most of the energy flow and nutrient cycling taking place on the site is being accomplished by noncommercial, seral plant species.

Once an adequate leaf area of the desired species has been established, biomass of these species is created. Some of this is lost again to respiration, leaving a net biomass accumulation. The magnitude of this respiration loss will depend on the climate, and there may be a minor effect of factors such as stocking density (surface area/volume relationships) and the distribution of biomass between different tissues that have different rates of respiration. The ratio of different tissues is a result of the allocation of net biomass production to these different tree components. This allocation is largely a function of the availability of the soil resources of nutrients and moisture, and of light. Of the two soil resources, nutrient availability is generally the most critical.

Not all of the net biomass production is retained as permanent biomass. A surprisingly large amount is lost to litterfall or root death. If we ignore the allocation of photosynthate to mycorrhizal fungi and other soil organisms, the annual production and death of fine roots (roots less than 2 mm in diameter) can account for between 50 and 70% of the net biomass production on nutrient-poor sites, and allocation of net production to ephemeral fine roots frequently exceeds the allocation to stemwood; if only we could harvest and use the biomass of fine roots without damaging the ecosystem! Allocation to mycorrhizae and rhizosphere organisms (organisms that live within 1-2 mm of a fine root) has not been well quantified, but it is believed to be large and may even exceed the allocation to fine roots in some cases. Losses to foliage, branch, and bark litterfall; to defoliation by herbivores; to the death of larger roots; and to individual tree mortality also reduce the net permanent biomass accumulation. The magnitude of the loss to ephemeral tissues is partly determined by genetics (e.g., deciduous versus evergreen trees; the number of years of needles retained by evergreens), but the allocation to fine roots and to mycorrhizae is largely a function of soil fertility.

Research over the past decade has shown that our forests vary much less in their total biomass production than in their accumulation of that production in stemwood. This poses the question of how forest management is affecting this allocation, and whether or not we could alter it in favour of harvestable and useable biomass components without impairing ecosystem function. If the trees have to work hard to find the soil nutrients they require to produce and operate the foliage they need to capture energy and grow, they will invest a lot of their available energy resources in fine roots. Much of the increased growth on a per hectare basis that results from either forest fertilization or the reduction in competition for resources following stand thinning or weeding is a result of a change in plant production allocation. It is not simply an increase in total tree production, although this occurs as well and is usually an important component of the stemwood volume response. Similarly, when we deplete soil resources through inappropriate management, we not only reduce total biomass production in our forests but we also increase the allocation of production to short-

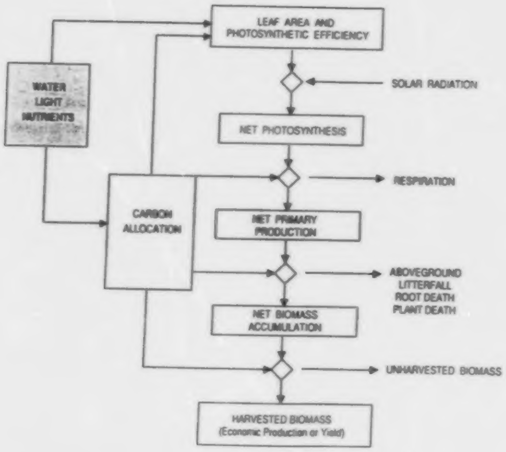

Figure 1. Diagrammatic representation of the major features of the production ecology of a forest ecosystem. The critical importance of the availability of soil resources in the capture of solar energy and its storage in harvestable biomass can be seen.

lived biomass components, or tissues that we cannot or do not harvest.

From this brief analysis (Figure 1), it can be seen that accruals to our timber capital will depend on the speed and success with which we reforest harvested areas, the success with which the leaf area capacity of the site is allocated to crop trees rather than to noncrop competitors (i.e., the success of vegetation management and the control of early plant succession), and the degree to which the crop trees are provided with the soil resources they need. Forest management can affect all of these variables. The climate of the area is also very important because it influences the maximum leaf area a site can carry, the length of the photosynthetic period, and respiration losses. However, fertilizer research on dry sites and in northern forests suggests that climatic limitations on growth (both summer drought and long cold winters) can act as much through their effects on soil processes and conditions that determine nutrient availability as through their direct effects on plant physiology. This offers the possibility of modifying the action of some climatic limitations on growth, and of ameliorating some of the potentially negative impacts of climatic change on Canada's forests, by improving soil nutritional conditions. Conversely, nutritional depletion of forest soils may render forests more susceptible to climatic controls of growth.

Representation of the Realities of Production Ecology in Growth and Yield Models

Traditional Growth and Yield Models

The volume or biomass of useful timber products that can be harvested from Canada's forests in the future will be affected by a variety of factors, including economic considerations; competition from alternative land uses; losses to fires, insects, and diseases; and the rate and pattern of harvesting our present forests. It will also be strongly influenced by the impacts of stand-level management on stand-level production ecology. It is appropriate to enquire, therefore, whether the stand-level growth and yield predictors that provide the stand-level inputs to whole-forest timber supply models are sufficiently sensitive to the anticipated changes in management strategies and environmental conditions to provide a believable foundation for such models.

Traditional growth and yield predictors are "historical bioassay" models. They project past patterns of biomass accumulation and stand development into the future. There can be little question that they are the most practical and believable method of predicting future forest growth for future environmental, site, and management conditions that are very similar to those of the past. They are very questionable, however, for dealing with future conditions that are significantly different. Considering the anticipated changes in management and concomitant changes in stand and site conditions, together with the expected changes in climate, the long-term predictions of historical bioassay growth and yield models are not convincing. Although they reflect the details of site-level production ecology implicitly, their failure to do so explicitly renders them inflexible in the face of future changes in growing conditions. Although traditional mensurational models will undoubtedly continue to be an important management tool for making short-term predictions of growth and yield, they are not appropriate for the long-term predictions that must be made if foresters are to be able to address issues of sustainable development and the contribution of the forestry sector to global warming.

Ecosystem Management Simulation Models

Although timber managers may be mainly interested in future timber yield, they must consider growth and yield in the context of the entire ecosystem of which the trees are merely one component if they wish to make believable long-term predictions. Historical bioassay growth and yield predictors are experience-based predictors. If we had rotation or multirotation experience of growth and yield under all the probable future growing conditions, experience-based prediction would probably continue to be the optimum approach to forecasting growth and yield. We lack such experience, however, and short-term experience is often a poor predictor of long-term experience. Research has shown that sites that have experienced significant declines in soil fertility and rotation-length productivity can sometimes support unchanged or even improved forest growth over the first one or two decades of the rotation.

We cannot afford to wait the several decades that it sometimes takes for experience to reveal the inappropriateness of certain management practices on certain sites. If we do so, we are obliged to accept the consequences for the rest of the rotation. We need to be able to predict such undesirable outcomes of management in the absence of appropriate experience. To do this, we must use ecosystem-level, knowledge-based prediction systems, either on their own or in combination with traditional historical bioassay approaches.

There are still difficulties associated with using purely knowledge-based growth and yield models. Either we are not able to build models of sufficient complexity to represent ecosystem function over an entire rotation accurately or, if we are able to do this, the input data demands of such models tend to put them beyond the operational reach of forest planners. However, by combining ecosystem-level historical bioassay models with some process simulation, we may be able to achieve reasonably practical and useable growth and yield predictors. These can be used to rank the probable consequences of alternative management strategies for growth and yield, stand-level economics, stand carbon budgets, and a number of other variables of interest under a variety of plausible future climatic conditions.

One example of this "hybrid simulation" type of ecosystem-level growth and yield predictor is FORECAST, a model currently being developed at the University of British Columbia. An earlier model that we developed, FORCYTE-11 (funded through the ENFOR program of Forestry Canada), is useful for ranking a variety of consequences of many aspects of stand-level forest management, but is unable to simulate some important stand treatments, several aspects of stand structure, and the entire question of the effects of climatic change on forest growth.

FORECAST uses the modelling approach that was originally developed at the University of British Columbia in the mid-1970s, and was then used as the basis for developing the FORCYTE series of models for Forestry Canada commencing in the late 1970s. This approach uses the historical patterns of biomass production, accumulation, and turnover in the species of trees, shrubs, herbs, and bryophytes (e.g., mosses) that are to be included in the simulation and then asks the question, Can these historical patterns be reproduced in the future given simulated changes in a variety of site conditions? In FORECAST, these include soil nutrient availability, soil physical condition (compaction, erosion), light competition, soil water availability and competition for water, and changes in seasonal temperature and soil moisture regimes.

In common with all other growth and yield models, models of this type cannot be used to make believable absolute predictions of growth, yield, and other outcomes over rotation-length or multirotation-length time scales in the northern forests that characterize most of Canada. None of our growth and yield "crystal balls" give us a clear picture over such long time scales. However, by harnessing our present knowledge of ecosystem function and production ecology, and combining it with the experience and knowledge of the past growth of Canada's forests, we can remove much of the uncertainty in the ranking of a variety of outcomes of alternative forest management strategies. We can make much better estimates of the relative sustainability of yields under different approaches to managing our forest landscapes, and we can begin to make predictions about whether or not forestry in Canada is contributing to the global "greenhouse problem" or is, in fact, providing a significant sink for the CO_2 component of the problem. Models such as FORCYTE and FORECAST simulate not only net primary production and its allocation to different tree biomass components but also the accumulation and turnover of dead organic matter in both unmanaged stands and stands managed under a wide variety of silvicultural regimes.

One of the great challenges facing foresters today is the public pressure to replace clear-cutting with other harvesting systems. Many of the ideas espoused by this movement are ecologically sound if applied to the appropriate type of forest ecosystem, but some advocates of "new forestry" have argued for uneven-aged management where this is ecologically inappropriate. Their ideas are impractical for harvesting some types of old growth, even though they might be valid for second-growth management on the same site. In many cases, the call is for modified even-aged silviculture rather than traditional uneven-aged management, and there is certainly a range of forest types in Canada in which conflicts between timber production and various nontimber values could be reduced by adopting some of the suggested changes.

In the absence of appropriate experience-based growth and yield predictors, it is difficult to evaluate the consequences of implementing such alternative silvicultural systems for future timber yields. Models such as FORECAST can be used to investigate some of the probable outcomes of shelterwood, two-story high forest, and "wildlife leave-tree" systems. FORECAST or FORCYTE can also be used to evaluate the long-term implications of retaining "large organic debris" for the maintenance of soil humus levels and soil fertility. However, there are many aspects of the microbial and wildlife ecology of large rotting logs that cannot be represented in currently available ecosystem simulation models. Where these play a significant role in determining site productivity, this deficiency reduces the value of the available models.

No attempt is made to describe the FORECAST or FORCYTE models in this paper. Reviews of the philosophy and approach used in FORCYTE can be found in Kimmins (1985, 1988, 1990) and Kimmins and Sollins (1989).

Potential Contributions of Ecosystem-level Management Simulation Models to Nutritional Forest Growth and Yield Prediction

FORCYTE and FORECAST are ecosystem-level models. Inevitably, they require a greater input of calibration data than the traditional growth and yield predictors, which are generally tree population models, and often not even that. In many cases, these population models are restricted to predictions about populations of logs or of tree stems. The KIS (keep it simple) principle (also known in scientific parlance as "Occam's razor") operates as much in growth and yield prediction as in any other aspect of life. The simplest, cheapest, and most practical way of getting a growth and yield prediction job done satisfactorily is the one that will normally be chosen. In the past, traditional growth and yield prediction methods have served us well, and will continue to do so for certain important prediction applications. However, I do not believe that these traditional predictors perform satisfactorily in answering many of the questions now being asked and dealing with many of the aspects of forestry for which the public is now holding us accountable.

We do not yet know whether or not the FORECAST or FORCYTE approach offers the simplest, cheapest, and most effective way of addressing these new and challenging ecosystem performance prediction needs. One thing is certain, however. To be able to answer these new questions, a much more comprehensive, ecosystem-level approach will have to be taken. This will be more expensive, more demanding of our knowledge and calibration data, and more demanding of verification and validation research than the traditional methods. Whether or not this extra effort will be justified can only be assessed in terms of how seriously we take the public demand and professional need to be able to predict the yield, economics, carbon budget, sustainability of yield, wildlife, and other consequences of stand-level management strategies that have not yet been tested, and to predict them under climatic conditions that are expected to change over the rotation. The FORECAST and FORCYTE models can provide an assessment of the accuracy of historical bioassay predictions for these altered future conditions.

Much of the data input requirements of these two models can be met using existing mensurational data, derived therefrom using biomass regression from the literature (or generated by the ENFOR program), and from published scientific data. In many cases, additional data will be required, but the models were designed to minimize the need for the more esoteric types of scientific data. If a commitment were made to pursue this approach, first-approximation calibration of these models should not pose insurmountable problems. At least the difficulties would be orders of magnitude less than the problems we will face if we fail to get believable prediction systems.

An "Ideal" Approach to Predicting Accruals to Canada's Timber Resources

The magnitude of the timber inventory in Canada's forests is the result of the balance between all accruals to this resource and all withdrawals. The answer to the question of whether or not we are harvesting this inventory too rapidly lies partly in an accurate definition of this balance and partly in our knowledge of how the inventory is distributed geographically and between different species, age classes and tree size classes.

On the loss side, considerable efforts are made to account for area and volume losses to insects, diseases, and fires, and we have reasonably good records of losses to harvest. On the accrual side, we have data on the areas planted, but our knowledge of the success and early performance of plantation is often incomplete. Our knowledge of the success of natural regeneration is often even worse, and our traditional yield models generally start only when the stand is "free to grow" or has reached a minimum merchantable tree size. The extremely important early stand establishment and development stage is not adequately considered in most of the growth and yield predictors; consequently, our estimates of the accrual of biomass and volume in young stands are often unsatisfactory. These same growth and yield predictors also fail to establish the stand-level balance over the rotation between accruals and losses of biomass (discussed earlier under production ecology). This is not a problem where the historical balance is repeated in the future, but it will constitute a significant problem if stand management and/or climatic change result in changes to this balance in the future.

An "ideal" approach to answering the question about overlogging would involve a variety of different levels of prediction. The use of geographic information systems (GIS) appears to be the best available approach to addressing those components of the rate-of-harvesting question that relate to the spatial distribution of the timber resource and harvesting patterns, i.e., economic accessibility of the timber resource, availability of desirable species mixtures for winter and summer logging, landscape diversity and wildlife habitat, and impacts on aesthetics, recreation, water resources, etc. Whole-forest models are needed for each timber supply area to project the consequences of different harvesting strategies over time for the future species and age-class structure of the forest, given the present age-class distribution and species composition. Such models are needed to make projections of future states of the spatially represented current forest conditions as provided by a geographic information system. Whole-forest models are also needed in the evaluation of long-term carbon budgets of timber supply areas. These regional carbon budgets will be greatly affected by the distribution of the area among different forest site types, age classes, and stand conditions. The inputs for these whole-forest models should come from hybrid, ecosystem-level, management simulation models that have been set up to represent the anticipated future management and environmental (e.g., climatic) conditions, or used to predict the relative outcomes of various possible future conditions.

Key questions about the sustainability of current harvesting levels must be answered at the whole-forest level. However, the accuracy of predictions from whole-forest models over anything more than the short-term (one or two decades) will depend on the accuracy of the predicted growth of the individual stands of which the forest is composed. Accurate answers about whether or not we are overharvesting our timber resource will ultimately be determined by the degree to which we have an accurate understanding of stand-level production ecology, incorporate this understanding into stand-level growth and yield models, and combine the resulting stand-level, rotation-length forecasts into regional timber supply predictions using whole-forest models linked to a geographic information system.

Discussion

Foresters have almost always claimed to be practicing sustained yield forestry, or at least sustained yield of timber products. The public no longer accepts this professional "act of faith." They want more tangible evidence that this is, in fact, happening. Most of the public appear to be unable to visualize the time scales associated with forestry. Environmentalists repeatedly "frame" images of freshly clear-cut or slash-burned sites and of aesthetic old-growth scenes, and "hang" these in the back of the public's mind as though these conditions were unchanging "forever," like pictures on a wall. It is difficult for a public that generally lacks biological and ecological knowledge to grasp the concepts of ecosystem change over time, of ecosystem resilience, and of ecosystem recovery from natural or human-induced disturbances. Many "activist" environmentalists appear to be either unwilling or unable to understand or accept the basic principles of ecosystem dynamics. Considering this great difficulty that the public has in foreseeing the future of our forests, it is particularly important that foresters employ scientifically credible, ecologically sound forest growth and yield predictors on which to base their rate-of-harvest calculations.

Forest ecosystems are resilient and do recover from a wide variety of natural and human-induced disturbances. However, this resilience varies between different types of ecosystem and with different types and intensities of disturbance. These differences are largely ignored in traditional forest growth and yield predictions. It is time that our traditional prediction systems were complemented by ecosystem-level simulation models that can be used to establish "ecological rotations" for different types of forest ecosystem, i.e., that combination of frequency and intensity of disturbance that will result in ecosystem recovery to some desired condition prior to subsequent disturbance and will maintain the average seral condition over the rotation at the desired level, in perpetuity (Figure 2). Considering the probable global climatic change, ecological rotations may well have to be adjusted for each succeeding rotation.

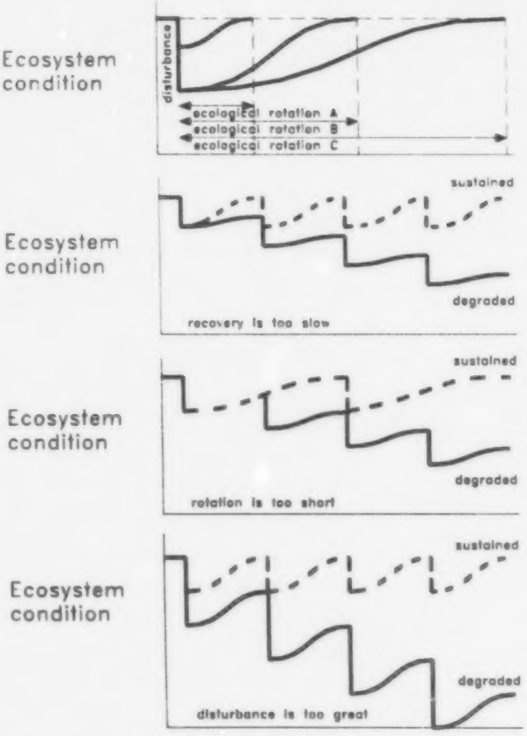

Figure 2. Graphical illustration of the concept of ecological rotations. The ecological rotation depends on the natural rate at which an ecosystem recovers from disturbance and the degree to which the ecosystem has been disturbed. Ecosystems will be degraded if recovery is too slow, the rotation is too short, or the disturbance is too great relative to the ecosystem's rate of recovery, the frequency of disturbance, and intensity of disturbance, as appropriate.

Conclusion

It is time to put forest growth and yield predictions on as sound an ecological basis as silviculture now is in British Columbia. I believe that the use of ecosystem-level management simulation models will eventually be to growth and yield prediction what the use of ecological site classification has become to silviculture.

Acknowledgments

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The Challenge of Substantiating Improved Yields from a Managed Forest

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Abstract

This paper outlines the approach taken by Weldwood of Canada Ltd. to intensively inventory a forest management licence in Alberta. A new approach was needed to estimate the growth and future yield of 100 000 ha of regeneration; to accurately forecast volumes, potential wood products, and habitat distributions of natural stands; and to project annual allowable cut (AAC) estimates into the second rotation. Supported by 30 years of growth and yield research, stand level growth models, managed stand yield tables, and a regenerated stand inventory system were developed within the context of an overall inventory systems approach. The main reason for this inventory was to quantify the stands. Significant increases in AAC can be realized if the site indices of regenerated stands are identified and coupled with managed stand yield tables. Improved growth rates could have a significant impact on rotation ages, yields, management strategies, wood supply analysis, and discretionary silviculture investments.

Résumé

Le présent article décrit l'approche adoptée par la compagnie Weldwood du Canada lors d'un inventaire intensif d'une licence d'aménagement forestier en Alberta. Il fallait avoir recours à une nouvelle approche pour estimer la croissance et le rendement futur de 100 000 hectares de régénération, pour prévoir avec précision les volumes, les éventuels produits du bois et la répartition des habitats en forêt naturelle ainsi que pour estimer la possibilité réalisable annuelle lors de la seconde révolution. S'appuyant sur 30 années de recherche sur la croissance et le rendement, des modèles sur la croissance d'un peuplement individuel, des tables de production de peuplement aménagé et un système d'inventaire d'un peuplement régénéré ont été mis au point à titre de cadre général d'inventaire. Cet inventaire avait pour but principal d'obtenir des données quantitatives sur le peuplement. L'identification des indices de station des peuplements régénérés conjuguée à des tables de production des peuplements aménagés peut permettre d'accroître de façon significative la possibilité réalisable annuelle. De meilleurs taux de croissance pourraient avoir des répercussions importantes sur l'âge d'exploitabilité, les rendements, les stratégies de gestion, l'analyse de l'approvisionnement en matière ligneuse et les investissements discrétionnaires au chapitre de la sylviculture.

Introduction

Weldwood of Canada Ltd., Hinton Division, manages approximately 1 000 000 ha of Crown forestland under a Forest Management Agreement (FMA) with the Province of Alberta. The forest is divided into five working circles, each managed as a sustained yield unit. The working circles are further subdivided into a total of 135 operating compartments based on operational constraints and age.

In 1988, Weldwood, then Champion Forest Products Alberta Ltd., and the Alberta Forest Service expanded the forest management area by 30% (225 000 ha), to its current size. Once current facility expansion is complete and mills are operating at capacity, 70% of the company's 2 400 000 m^3/year demand for coniferous wood supplies will be realized from the forest management area, whereas the remaining 30% will be purchased as chips and roundwood. Approximately 57 000 m^3/year of trembling aspen is harvested and sold. The FMA stipulates that by 1993 Weldwood will have conducted a feasibility study and will indicate whether it plans to utilize the deciduous timber growing on the forest management area. Weldwood has proposed a preliminary deciduous annual allowable cut (AAC) of 195 000 m^3/year and is examining several processing options. This paper describes Weldwood of Canada Ltd., Hinton Division's inventory programs, preexpansion and postexpansion and how recent developments in growth and yield will substantiate improved regenerated yields.

Inventory Systems Used in the 1980s

Prior to "expansion," two inventory systems were employed. A photo point sample (PPS) or management inventory determined forest level composition and structure for the entire FMA area. Each point represented an equal proportion of the net productive forestland base (permanent water, roads, permanent deletions, and dispositions are removed) in a specific working circle. The purpose of the inventory was to establish working circle AACs and approximate compartment volumes and harvest schedules. The system comprised 6000 photo points on a 40 chain (804.7 m) grid across the forest management area. When a photo point sample was established in a cutover, the average stand type (species, density, height class, and age) for the cutover was determined.

An operational inventory was also used to collect detailed stand level information (species, density, height, and age) in operating compartments approximately 2 years before harvest. All stands 0.5 ha and larger were identified. The data were used to calculate compartment volumes, to develop harvest plans, and to produce operational schedules.

The relationship between the two inventories was Weldwood's system of about 3000 permanent sample plots (PSPs). The plots were originally established in the late 1950s as a continuous forest inventory (CFI). In the early 1970s, the focus of the PSP system switched to developing growth and yield information for both natural and regenerated stands, and for validating AAC estimates. The PSP data were analyzed and aerial stand volume tables (ASVT) were produced, the most recent in 1984. These height driven tables describe net merchantable volumes for 30 cover types (species, density) in 1 foot (30 cm) height intervals. In 1986, an increase in the AAC of approximately 20% was realized as a result of using the actual growth rates from fire-origin PSPs rather than empirical volume/age curves.

Cutovers were assessed, up to 8 years after logging, using a regeneration stocking survey. Until recently, only stocking and species were recorded, with no attempt to identify differences in growth or yield compared with fire-origin stands. As a result, the information could not be incorporated into the AAC analysis.

Estimates of Natural and Managed Stand Growth and Yield

In 1984, Weldwood examined the feasibility of using the PSP data base as a foundation for predicting yields of regenerated stands (W.R. Dempster and Associates Ltd. 1984). Early height growth of these stands, calculated from PSP data, was significantly greater than that of fire-origin stands. Several management scenarios were examined and the results suggested that a combination of improved height growth and stocking control could increase volume yield substantially (Table 1).

A subsequent report (W.R. Dempster and Associates Ltd. 1985) examined the early growth rates of regenerated lodgepole pine stands in relation to those of fire-origin stands on the same sites. The project used two investigative approaches: analyzing PSP data from older regenerated stands and the fire-origin stands that grew on the same plots, and destructively sampling top height trees (average height of the 100 largest diameter trees per hectare) in a system of paired plots in adjacent fire-origin and regenerated stands. The early height and diameter increment (Table 2) were almost twice as high in the regenerated stands as in the fire-origin stands. Height variability was also lower in regenerated stands; indicating more consistent growth performance. Based on these findings, regression equations were used to forecast site index as a function of a simple field measure of growth intercept (height interval 5 years above breast height).

The results of this study (Udell and Dempster 1986) illustrated the potential volume lift (Table 3). The data base from previous work was supplemented with measurements of height development and age in long-established regenerated PSPs. The regenerated stand site indices were compared with those of the original fire-origin stands growing on the same sites or locations.

Early growth rates of young stands were investigated in 1989 (W.R. Dempster and Associates Ltd. 1989). The analysis supported the trend, stated in previous reports, that early growth rates of harvest-origin forests are greater than early growth rates of fire-origin forests. However, it should be noted that the sample size was small and that the project was designed to examine changes in height growth, not volume.

Previous comparisons between harvest-origin stands and fire-origin stands of lodgepole pine indicate an increase of up to 90% in early height growth. This study suggests that increases of 50-70% in early height growth between young and old fire-origin pine are possible and that only 20-40% of the improved growth rates of regenerated stands may be due to management practices.

Thirty years of growth and yield research, combined with the experience of field staff, showed that substantial improvements in yield could be realized from regenerated stands if they could be proven, and if the stands could meet free-to-grow standards and be kept

Table 1. Potential volume increases in regenerated stands

Scenario	Volume Increase Relative to Scenario 1
1. Empirical site index and stocking	-
2. Empirical site index, improved stocking	+13%
3. Regenerated site index, empirical stocking	+39%
4. Regenerated site index, improved stocking	+61%

Table 2. Differences in early height increment between fire-origin and regenerated stands based on stem analysis

Growth Intercept (years above breast height)	Number of Plot Groups	Stand Origin	Height Increment		
			Mean (m)	Standard Error (m)	Coefficient of Variance (%)
5	22	Regenerated	2.21	0.39	17.7
		Fire	1.15	0.38	33.4
10	16	Regenerated	4.52	0.78	17.3
		Fire	2.39	0.74	31.1

Table 3. Potential yields from regenerated stands

Origin	Model	Site Index (breast height at age 50)	Top Height (m)	% Increase in Top Height	Merchantable Volume (m^3/ha)	% Increase in Volume
Fire	Height development over a 5 year interval; best combination of 5 and 10 year growth intercepts	13	15.8	-	126.2	-
Regenerated		16	19.3	25.6	220.5	74.7
Regenerated		18	20.9	31.9	262.6	108.1

free-to-grow. The latter may not be easy in a province where herbicides are not permitted for forestry use.

New Directions in Growth and Yield

To quantify the volume gains, a growth and yield cooperative was formed between Weldwood of Canada Ltd., Hinton Division, and Proctor and Gamble Cellulose Inc. of Grande Prairie. Independent of the cooperative, Weldwood developed a regenerated stand inventory (RSI) to describe the stands that contribute to the gains.

The goal of the cooperative is to establish managed stand yield tables, using stand level models, for white spruce, lodgepole pine, and trembling aspen in the eastern slopes region of Alberta. The distance dependent model TASS (tree and stand simulator), developed by Ken Mitchell and Associates, and distance independent growth model SPS (stand projection system), developed by James D. Arney, were chosen. TASS is being calibrated to the Alberta data by British Columbia Ministry of Forests Research Branch staff (in exchange for temporary use of the cooperative's PSP data base) in collaboration with W.R. Dempster and Associates Ltd. The objective is to model the development of pure lodgepole pine and white spruce stands. SPS is being calibrated by D.R. Systems Ltd. and Thomson/FORTRENDS staff to model deciduous/coniferous and coniferous/coniferous mixed-wood stands. An observer from the Alberta Forest Service (AFS) is involved to facilitate information exchange and to verify the reliability of the results.

Stem mapping was recently completed by Weldwood and Proctor and Gamble on a total of 173 PSPs for both SPS and TASS. The majority of the PSPs were located in regenerated stands. Approximately 120 lodgepole pine, white spruce, and trembling aspen trees were destructively sampled to establish diameter/crown relationships for SPS. Initial versions of both models are near completion.

Current Inventory System Development for the 1990s

Concurrent with expansion, a new and more sophisticated inventory process was initiated. It is driven by the need to quantify the growth and yield of 100 000 ha of regeneration, predict with greater confidence the near-term volumes and product distributions of fire-origin stands, identify and model wildlife habitat, and project the AAC into the second rotation.

Implementation of the current system is about 70% complete. The revised system will consist of the following eight components, linked with a geographic information system (GIS):

1. A photo point sample inventory of natural stands
2. An operational inventory
3. A regenerated stand inventory

4. An inventory-updating process
5. Pure and mixed-wood stand growth models
6. Managed stand yield tables for regenerated stands
7. New aerial stand volume tables for fire-origin stands
8. A block-level cut-control program

The PPS inventory was expanded to over 8000 points, reflecting the expanded forest size, and will supply broad-scale information for all compartments at least 30 years from harvest. The data from operational inventories will be used to assess near-term (less than 30 years) opportunities for integrated resource management and forecast volumes, sawlog/pulplog ratios, and wildlife habitat distributions. The RSI will supply yield information on the emerging second growth forest, and data for integrated resource planning and forest-level treatment decisions. The PSP system will be expanded by approximately 200 plots to capture needed information in the new licence area. It will be used to monitor long-term growth and to calibrate growth and yield models for all three inventories over the expanded forest management area.

The two stand growth models are being calibrated and will be used to evaluate treatment response and generate managed stand yield tables for pure and mixed-wood stands. The ASVTs will be recalculated to incorporate eight more years of growth data. An inventory-updating system linked to annual operating plans and annual aerial photography is also being planned. A block-level cut-control program, which ties volume estimates from harvest planning to scaled volume and logging residue, is under development.

Regenerated Stand Inventory

In comparison to data collection and modeling efforts, the RSI is relatively simple. It is an inventory of stand structure, species composition, and productivity, and it gathers data for both silviculture and wildlife management needs.

The objectives of the RSI are

1. To substantiate AAC increases based on improved growth rates
2. To examine, at the forest level, any allowable cut effect opportunities available through discretionary silvicultural investments
3. To examine treatment options that would mitigate wood supply problems
4. To assess deciduous utilization opportunities using the quality, distribution, and volume of regenerated stands, in addition to mature timber
5. To assess the pending free-to-grow requirements and have an existing survey system capable of collecting required data
6. To better assess wildlife habitat distribution on all regenerated stands
7. To justify and assess silvicultural problems, programs, and budgets using stand-specific information

All cutovers are stratified into three broad strata based on the knowledge of a silviculture forester about cutover composition. A systematic grid pattern with varying plot intensity is used to reflect the degree of confidence in the regenerated stand composition. Two circular plots are established at the same plot centre. The smaller silviculture plot has a radius of 2.82 m (1/400 ha), whereas the site index plot has a radius of 7.99 m (1/50 ha).

Data in the silviculture plot are stratified into three tree layers, and height and species counts are recorded for residual, noncrop, and crop tree layers. Two well-spaced crop trees are measured for height, leader growth, and root collar diameter, and assessed for damage. The number of snags are tallied and the height and percent ground cover for woody, nonwoody, and moss/lichen vegetation are recorded.

Within the site index plot, two top height trees are selected and the 5 year growth intercept, height to live crown, and total height are measured. Polygons with uniform site index, and understory and overstory composition will be delineated on orthophoto sheets, digitized, and loaded into the GIS.

Applications that are being planned include a forest level analysis of silviculture treatments designed to ease a possible short-term decrease in harvested tree size in 30-40 years, an autocorrelation of plot characteristics to determine stand boundaries in comparison with the manual method being used, and a forest level ranking of candidate blocks for cleaning based on specific height ratios and density/stocking relationships between crop and noncrop species.

Preliminary Results

Preliminary analysis on data collected from one working circle indicates that the average site index has increased from 13 to 17 m at a breast height age of 50 years. Based on the improved site index, preliminary projections for C density lodgepole pine were made with TASS to indicate volume and diameter estimates at a rotation age of 90 years (Table 4).

The difference between the mean annual increment of fire-origin and planted stands represents a potential allowable cut effect of 2.81 $m^3 \bullet ha^{-1} \bullet year^{-1}$. The actual value would be determined by prorating mean annual increments by treatment area.

Table 4. Preliminary estimates of yield and diameter from regenerated stands using projections from the TASS model

Management Regime	Density (stems per ha)	Gross Volume (m^3/ha)	Mean Annual Increment ($m^3 \cdot ha^{-1} \cdot year^{-1}$)	Site Index (breast height at age 50)	Average Diameter (cm)
Average fire origin	30 000+	176	1.96	13	15.0
Natural regeneration	8 000	383	4.26	17	18.9
Natural regeneration	8 000				
Space at 4 m	2 500	391	4.34	17	19.6
Plant	1 600	429	4.77	17	22.7

Concluding Notes

Four statements can be made about verifying improved yields from managed stands and the implications of doing so.

1. Substantiating improved regenerated yields required a long-term growth and yield program, an exceptional PSP program, and a responsive inventory system.
2. The RSI gathers the spatial information necessary to substantiate improved growth rates.
3. Because the AAC is based upon growth, it will continue to increase as more and more fire-origin stands are converted to managed stands.
4. Managed stands and young fire-origin stands have higher early growth rates than those of old fire-origin stands. This could be due to fire severity, initial densities, or long-term climatic change.

The cumulative effect of this program has significant implications for growth projections and supply analysis, discretionary silviculture budgets, and forest management strategies.

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Timber Management in New Brunswick

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Abstract

Forest management in New Brunwick has evolved during the past decade in response to new policy and legislation, a better understanding of forest dynamics and the value of nontimber resources, new information-management technology, and a better appreciation of the planning process. This paper reviews these changes and describes the current forest management system in New Brunswick. The planning cycle is continuous, involving forest inventory, growth, and yield forecasting; the design of management activities; operational planning and implementation; and monitoring. The 1987 forest management planning process is described, and factors controlling the sustainable softwood supply are discussed. The major avenues identified for increasing softwood supplies include developing new silviculture tactics, practicing more silviculture, improving harvest block layout, and increasing the use of partial harvesting or thinning. Equally, softwood supplies will be diminished as a result of reserving more land from forest management, reducing silviculture activities, or restricting the time needed between harvesting adjacent blocks. The 1992 management cycle will undoubtedly include more changes in response to public values, technology, and demands from multiple users on the resource. Forest management principles, however, should not change, and these will help guide management through the challenges of the 1990s.

Résumé

Au cours de la dernière décennie, l'aménagement forestier a évolué au Nouveau-Brunswick à la suite de l'adoption de nouvelles politiques ou des lois, d'une meilleur compréhension de la dynamique de la forêt et de la valeur des ressources autres que forestières, de l'apparition d'une nouvelle technologie de gestion de l'information et d'une plus grande valorisation du processus de planification. Le présent article examine ces modifications et décrit le régime actuel d'aménagement forestier en vigueur au Nouveau-Brunswick. Le cycle de planification est continu et comprend l'inventaire des forêts, la prévision de la croissance et du rendement, l'élaboration d'activités d'aménagement, l'établissement et la mise en œuvre d'un plan d'opérations ainsi que sa surveillance. L'auteur décrit le processus de planification de l'aménagement forestier de 1987 et examine les facteurs régissant le développement durable de la réserve de bois de résineux. Parmi les principaux moyens identifiés pour accroître l'approvisionnement en bois de résineux, mentionnons la mise au point de nouvelles méthodes sylvicoles, la multiplication des interventions sylvicoles, l'amélioration de la disposition des carreaux de coupe et un recours plus fréquent à des coupes ou des éclaircies partielles. En outre, l'affectation de plus grandes superficies à des utilisations autres que l'aménagement forestier, la diminution des activités sylvicoles ou le raccourcissement de la période s'écoulant entre la récolte des blocs adjacents feront diminuer la réserve de bois de résineux. Le cycle d'aménagement de 1992 comportera sans aucun doute d'autres modifications en réponse aux valeurs du public, à la technologie et aux demandes provenant des multiples utilisateurs de la ressource. Les principes d'aménagement forestier ne changeront toutefois pas et aideront les responsables à relever les défis des années 90.

Introduction

Timber management in New Brunswick has evolved rapidly during the 1980s. The primary driving forces behind this evolution include (1) recognition of the precarious balance between sustainable timber supplies and consumptive demand; (2) a new policy and planning framework set out in the 1982 Crown Lands and Forests Act; (3) an improved understanding of forest resource dynamics; (4) the increased value being placed on nontimber aspects of the resource; (5) the availability of new information-management technology, particularly geographic information systems; (6) higher quality resource information; and (7) a heightened appreciation of the linkage between strategic and operational levels of resource planning and action.

These factors have certainly changed the management of New Brunswick's forests, but have they led to successful management? If success means perfection, the answer is undoubtedly "no." If success means significant, ongoing improvement in management, the answer is a qualified "yes." The qualification relates not to whether management perfection is ultimately achieved, but to whether meaningful improvement in management is sustained. Continued improvement will hinge first upon our ability to identify the shortcomings and limitations of present management, and second, upon our ability to design measures that overcome those weaknesses.

This paper will review the New Brunswick Crown land management process for the purpose of identifying areas where research, development, new practices, and additional resource information can most effectively advance timber management capabilities. The discussion will proceed through (1) identification of the general planning context and timetable; (2) elaboration on specific aspects of the management process; (3) presentation of the most recent forecasts of forest production; and (4) discussion of the implications of those forecasts as they pertain to improving management practices in the future. Although timber management is merely a subset of overall forest management, we will focus on the former to simplify the discussion.

Management Context and Timetable

Figure 1 provides an overview of the management context for Crown forests in New Brunswick. Five major processes are evident, namely (1) inventory (data-base creation); (2) stand growth and yield forecasting; (3) management strategy design; (4) management strategy implementation; and (5) performance monitoring.

1. Forest inventory characterizes the physical resource in an information format for two purposes, the first of which is to quantify the present state of the resource. The second and most important purpose is to initialize forecasts necessary to predict the future state of the resource. The New Brunswick forest resource data base is managed within a geographic information system that provides more realistic resource characterization by allowing for geographic representation.
2. Stand growth and yield forecasting use the resource data base, together with stand growth models, to predict development of stand characteristics (e.g., fibre or log volume, browse, thermal cover) over time as they may be affected by a range of contemplated actions, including a variety of silviculture and harvesting practices and no intervention at all.
3. Management is designed using forest level forecasts that are made with a forest projection model supplied with biological (stand yields and forest structure) information about the forest. The forest model receives management inputs in terms of silviculture and harvesting, imposes them on the forest as specified, and forecasts the long- and short-term forest level consequences of those actions. Each forest level forecast provides a set of expected outcomes specific to each strategy tested, and these expectations provide the basis for selecting the strategy that *appears* to best attain management objectives. It is important to note that expectations are based on forecasts about the future and, thus, include some degree of uncertainty.
4. The chosen strategy is then converted to a form that is operationally feasible and is subsequently implemented on the ground. During implementation, the resource changes physically as activities are undertaken and due to the natural dynamics of stand development.
5. This physical change constitutes the *reality* of forest development and it must be compared with the original forecasts of *expected* development to determine if expectations and reality coincide. In all likelihood, the two will diverge and a comprehensive monitoring system must be in effect to measure the degree of divergence and, most importantly, to identify the underlying causes. These may include forecast errors (due to limitations in resource information and understanding of dynamics), errors in implementation, the occurrence of unforeseen events, or a combination of all three. Reconciliation of expectations and reality is undertaken to formulate remedial measures appropriate to bring the two back into alignment.

This reconciliation closes the forest management loop that operates in iterative fashion through the five steps of inventory, stand yield forecasting, management design, implementation, and monitoring and reconciliation. In New Brunswick, this iterative process operates on a 5 year time cycle. The specific timetable is presented in Figure 2. As shown, there is overlap in the process, so that during management implementation within each cycle, inventory and stand yield preparations are being made for the next cycle.

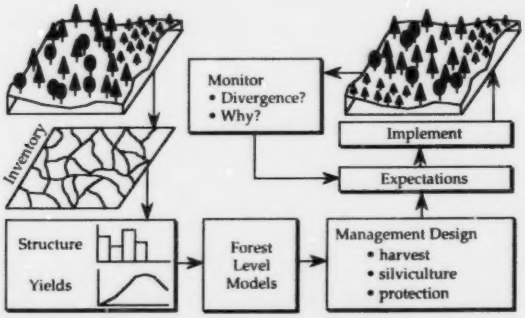


Figure 1. General context for timber management on New Brunswick Crown land. See text for discussion.

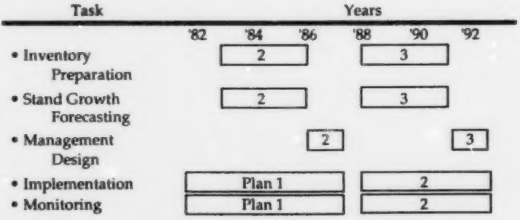


Figure 2. Management planning timetable for New Brunswick Crown lands.

In this framework, management planning is a continuous process, not a discrete flurry of last minute activity aimed at submitting the next plan on time. The process promotes systematic timber management improvement when the most serious limitations in each planning cycle can be recognized, addressed in some appropriate fashion, and eliminated or reduced in subsequent cycles. Table 1 illustrates the history of such improvements dating back to the mid-1970s. It is interesting to note how the nature of the problems has shifted over the years among policy issues (management control and nontimber values), information issues (inventory quality and growth and yield data), and information management issues (forest development models and geographic information systems (GIS)). As the 1992 planning cycle is conducted, new problems will emerge and the challenge to timber management will be to find new solutions to the new problems.

Components of the Planning Process

Having looked at the timber management context and timetable in overview, it is worth focussing on the mechanics of management planning as currently practiced. Figure 3 depicts the six components of the process by which management plans are formulated and evaluated. Each of the six components will be discussed in sequence.

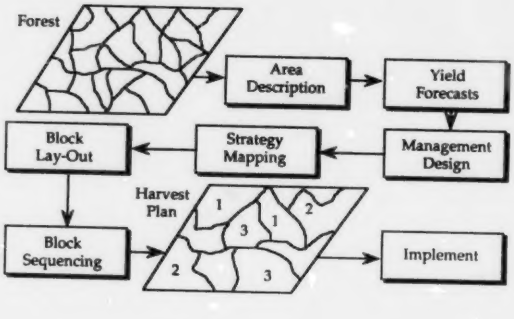


Figure 3. Steps by which timber management plans are developed for implementation.

Area Description

Starting with the productive forest base defined in the inventory, the area description characterizes each stand with respect to two types of factors as listed in Table 2. The first set relates to biological traits that directly correlate to growth of the stands themselves, and include species mix, site quality, and suitability for various harvest and silvicultural treatments. The second set of factors relates to the physical availability of each stand for harvest. This identifies all stands to be removed from the harvestable land base for environmental (e.g., riparian buffers and ecological reserves), legal (e.g., maple sugar leases), and operational (e.g., slope) reasons. The GIS capabilities help execute this step via digitization of the relevant exclusion areas, which are then overlaid on the inventory to define the net land base available for harvest. It is important that area identification be on a site-specific basis because there tends to be a concentration of certain stand types in the

Table 1. History of forest management improvement in New Brunswick through remedying limiting factors

Management Cycle	Limiting Factors	Remedial Measures
1970s	- lack of management control	- Crown Lands and Forests Act
	- failure to address forest dynamics in planning	- replacement of AAC formulae with forest dynamics model
1982	- inventory quality	- new inventory design and complication
	- lack of geographic linkage between strategic and operating plans	- GIS inventory storage and spatial depiction of management strategy
	- lack of realism in forest dynamics model	- new forest dynamics model
1987	- insufficient consideration of nontimber values	- habitat supply forecasting methods
	- inflexibility of forest dynamics model	- revised forest dynamics model
	- uncertainty of yields for regenerating and overmature stands	- new PSP network coupled with stand model formulation
1992	- to be discovered	

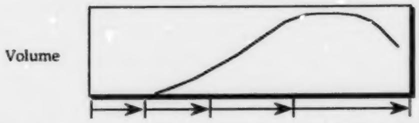
Table 2. **Factors used to characterize stands with respect to stand development and availability for harvest**

Biological Factors	Harvest Availability
1. Species composition	1. Deer wintering areas
2. Stand maturity (vigour)	2. Riparian buffer zones
3. Site quality	3. Ecological reserves
4. Harvest method suitability - clear-cut - two-pass even-aged - cutting cycle partial removal	4. Nontimber leases 5. Parks 6. Operationally inaccessible
5. Silviculture suitability - planting - juvenile spacing - commercial thinning	

removal areas (e.g., riparian buffers are dominated by mature softwood).

Stand Yield Forecasting

On the basis of biological traits assigned in the area description, stands are aggregated into classes for the purpose of predicting stand development. Forecasts are made for the development of existing natural stands, pre- to postharvest transition, naturally regenerating stands, and stands under silvicultural management. The approach to stand forecasting is illustrated in Figure 4. The main determinants of stand growth change as stands develop; consequently, no attempt is made to construct one general model for application to all stand conditions. Four individual models have been formulated, each to address a specific stage of stand development. This approach makes model construction more tractable in that each model is structured only to incorporate those factors most powerful in affecting growth during each developmental stage.



Growth Factors	Establish	Regenerate	Growth	Stable & Decline
Micro-Site	•			
Macro-Site	•	•	•	
Vertical Comp.	•	•	•	
Horizontal Comp.		•	•	
Insects/Disease			•	•
Age				•

Figure 4. Key stages of stand development and factors regulating growth. Stand forecasting models are constructed for each stage.

To compose a full yield forecast for the life of each stand requires that each stand be processed through each model in sequence. This, of course, requires care in model construction to ensure that the output from each model provides suitable initialization for the next. Variables predicted in each forecast include conventional measures of volume and piece size and have recently been expanded to include measures of habitat suitability to evaluate habitat supply for wildlife.

Management Design

The area description and stand yield forecasts are set up as inputs to a forest development model for the purpose of identifying appropriate management strategies. The current approach relies on simulation of forest development in which the short- and long-term impacts of an imposed set of management inputs are forecast for a variety of indicator variables (Figure 5). The forest level performance is a function of the forest condition itself, as well as the nature, timing, and amount of management inputs. The desirability of any strategy is a value judgement applied against the pattern of resultant forest performance indicators. Traditionally, these indicators have been restricted to timber values, but increasingly nontimber values are being added as indicators of forest performance.

The quality of management design is governed by the creativity used in formulating management inputs, and the comprehensiveness of the output indicators. With each management planning cycle, the attempt has been to broaden the array of input alternatives and to increase the set of output indicators to conform to changing forest management objectives and concerns.

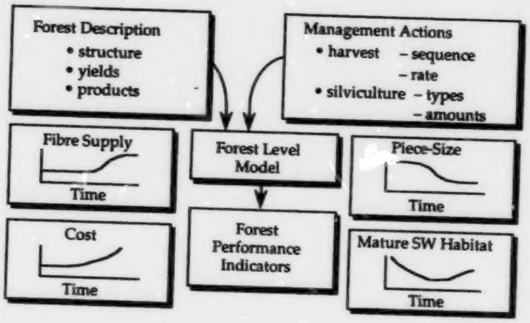


Figure 5. General concept of timber management design using forest level model to forecast important indicators of forest performance.

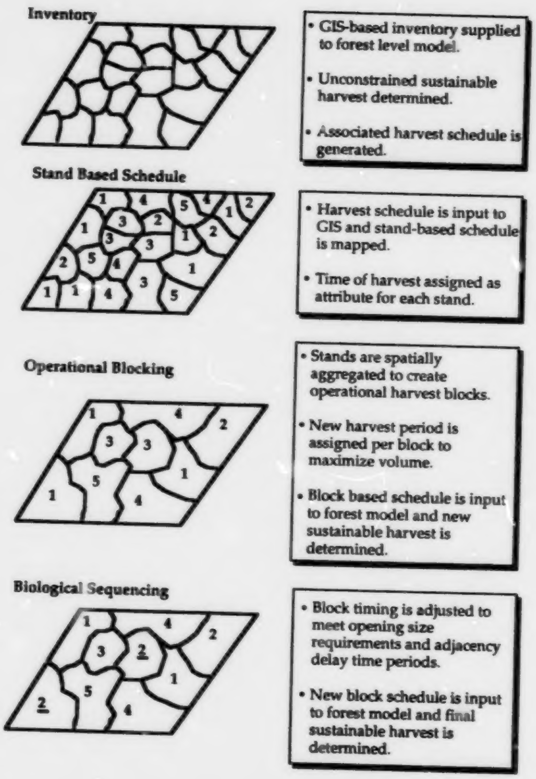
Beginning with habitat availability for deer and mature softwood forest dwellers, the New Brunswick management process is being modified to more fully portray the implications of selected strategies with respect to nontimber values. The intent is to better inform decision-makers with respect to the nature and extent of trade-offs associated with any contemplated strategy. The final step in management design is to select the one strategy (i.e., set of inputs) that, based on indicators, is expected to best attain management objectives.

Geographic Configuration

To this point, management design has not addressed the geographic configuration of the resource. In fact, prior to 1987, the process stopped short of geographically configuring the strategy, leaving an obvious and serious discrepancy between actions intended and those actually implemented. Current methods greatly reduce that discrepancy by using GIS capabilities to geographically depict the activities associated with the selected strategy. This is accomplished by establishing a linkage between stands in the inventory and classes input into the forest model. This linkage is then retraced once a forest level strategy is selected so that it can be defined geographically on a stand-specific basis. The result is a stand-based spatially referenced harvest schedule in which each stand is assigned a time of harvest as indicated by the forest level analysis (Figure 6, top).

Block Layout

Rarely, would such a stand-based pattern of activities be operationally feasible, so the stand-based strategy is modified by geographically aggregating stands into operationally feasible blocks (Figure 6, middle). The objective in block layout is to meet operating requirements and at the same time to maintain as much homogeneity with respect to harvest timing as possible between stands configured in the same block. Inevitably, stands of different harvest timing will be configured together and depending upon the variation in *volume change* between stands within blocks, the consequences of the blocked plan will differ from those of the unblocked plan. Invariably, the former will be less productive than the latter, with the important question being how much less. To answer this question, the blocked strategy (in which blocks are the decision units) is reprocessed through the forest level model. The difference in forest level outputs between the stand-based and block-based strategies is the effect of converting the theoretical plan into an operational plan.



- GIS-based inventory supplied to forest level model.
- Unconstrained sustainable harvest determined.
- Associated harvest schedule is generated.

- Harvest schedule is input to GIS and stand-based schedule is mapped.
- Time of harvest assigned as attribute for each stand.

- Stands are spatially aggregated to create operational harvest blocks.
- New harvest period is assigned per block to maximize volume.
- Block based schedule is input to forest model and new sustainable harvest is determined.

- Block timing is adjusted to meet opening size requirements and adjacency delay time periods.
- New block schedule is input to forest model and final sustainable harvest is determined.

Figure 6. Process of creating a geographically based harvest schedule incorporating operational and biological requirements. See text for discussion.

Block Sequencing

The process must be taken one step further to account for biological factors that must be considered in harvest activities.

In consideration of the geographic distribution of wildlife habitat, management on Crown forests in New Brunswick requires that a certain maximum-sized opening not be exceeded. This is accomplished by assigning a harvest delay period between adjacent harvest blocks, which prevents them from coalescing into extensive areas of uniform stand condition. The block sequencing process restricts harvest timing so that the required adjacency delay period is maintained. This involves systematically examining blocks and their neighbours to reassign harvest block timing where necessary to meet the adjacency delay requirements (Figure 6, bottom).

As with blocking itself, harvest block sequencing further reduces timber availability when the most productive harvest timing per block cannot be implemented due to adjacency considerations. Nonetheless, it is the forest production after block sequencing that must be assessed because *it is this strategy that will finally be implemented*. To evaluate forest production for the final plan, the blocked strategy, after modification for adjacency requirements, is rerun through the forest level model. The resulting sustainable harvest becomes the actual annual allowable cut and is the basis for regulating harvest activities and allocating volumes to mills.

At this point, the harvest rates are tied directly to the strategy to be implemented, and the strategy to be implemented is both operationally feasible (due to blocking) and biologically acceptable with respect to the biological requirements of opening size and block adjacency imposed at the time of plan development. The strategy is then implemented and the monitoring process is activated to determine (1) if stand development is as expected, (2) if silviculture is executed as planned, (3) if blocks are harvested as planned, and (4) the reasons behind any deviations that occur.

1987 Timber Supply Forecasts

The general procedure outlined above was performed in the development of the most recent (1987) forest management strategies. It is informative to review the results of those strategies both to define the present state of affairs and to indicate how things can and should be improved for the upcoming 1992 process.

In 1987, the previously described planning methodology was performed for each of the 10 licenses into which the 3.5 million ha Crown forest is divided. The sustainable softwood supply, summed across the 10 licenses, was approximately 3.9 million m^3/year. The harvest rate is forecast to be sustainable under an ongoing silviculture program consisting of 10 000 ha planted and 8 000 ha precommercially spaced annually. The total softwood harvest from Crown land averaged 3.75 million m^3/year between 1986 and 1988, revealing a relatively tight balance between supply and demand. The tight nature of this balance indicates the importance of judicious management to ensure a continuing supply of timber for the province's forest industry.

Although the harvest level is sustainable over the long-term (80 years is the length of the planning horizon), two other indicators of forest development manifest rather sharp changes (Figure 7). The first is the total operable growing stock, which exhibits a significant reduction from present to 2030, followed by a period of gradual growing stock accumulation. The declining segment of this profile results from progressive harvest through the preponderance of mature natural stands, which removes operable volume from the forest more rapidly than it is replaced by recruitment of young regenerating stands into the operable inventory. What is most significant about the growing stock profile is that the forest can sustain the 3.9 million m^3 annual harvest throughout the period of dramatic growing stock decline. This results because harvesting in this case converts the forest from one dominated by stands of high volume but minimal growth to one of more normal structure, containing significantly lower average stand volume but manifesting much higher stand growth rates. Simply in terms of volume production, harvesting has made the forest more productive by changing the present forest to one of younger, more uniform structure.

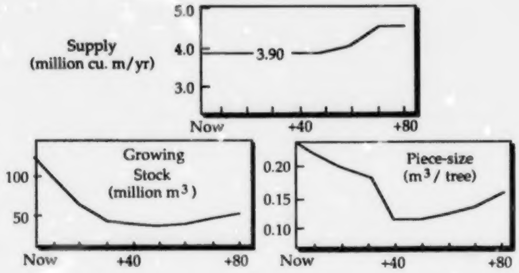


Figure 7. Sustainable softwood supply, growing stock, and piece-size forecasts from 1987 management plans for New Brunswick Crown forest.

The interaction between harvest and forest structure change underscores a flaw in the "balance sheet" approach to evaluating forest performance. This approach, in which a surplus of accruals over depletions is a sign of "good management," could lead to the conclusion that the New Brunswick forest is in a state of decline. The sustainability of the harvest is evidence to the contrary, and the growing stock decline is simply an inevitable consequence of the present forest structure and stand composition. The balance sheet approach, although attractive in its simplicity, is an uninformative model because of its failure to account for the structural dynamics of an unbalanced forest structure.

The second interesting indicator is the change over time of the mean harvested piece-size (volume per tree). Figure 7 shows the typical pattern of mean piece-size for New Brunswick Crown forests. The volume per tree falls off dramatically from 0.28 m^3/tree today to approximately 0.13 m^3/tree 40 years hence. This trend shows that, although the total harvest of 3.9 million m^3 can be sustained annually, the proportion of that harvest available in high volume trees cannot. This situation has serious implications for the sawlog industry and the decline in piece-size can only be offset by total harvest reduction, modifying harvesting practices, and/or changing the size and composition of the present silviculture program. The nature of the sawlog volume problem was highlighted in the 1987 management planning process, and the issue is targetted for a more thorough analysis in the upcoming 1992 cycle. More thorough analysis requires not only comprehensive evaluation of alternative strategies to mitigate the impending tree size reductions, but clarification of the provincial policy with respect to piece-size targets as well.

Figure 3 presented the steps involved in developing timber management strategies and it is interesting to review how decisions associated with some of those steps influence the availability of timber. Key influences on wood supply relate to (1) the area reserved from timber harvest in the area description step; (2) the silvicultural inputs made in the management design step; (3) the nature of harvest block configuration performed in the block layout step; and (4) harvest timing choices made in the block sequencing step. Figure 8 reveals how the sustainable timber supply is affected by decisions made in each of these four steps in the 1987 management planning process.

A maximum harvest of 4.85 million m^3 can be sustained annually if no land withdrawals are made and if all areas suitable for conventional planting and precommercial spacing are treated. Introducing the current reserves for riparian buffers, deer wintering areas, inaccessible slope, etc., reduces the available harvest by 10% to 4.37 million m^3/year. The silviculture program developed in the management design step was constrained by budget limitations; thus, only a portion of the total potential treatment area could, in fact, be silviculturally treated. This constrained silviculture program further reduced the sustainable harvest by 5% to 4.15 million m^3/year.

The block layout required to convert the original strategy into an operationally feasible one created an additional 4% reduction in harvest to 3.96 million m^3/year. This reduction occurs because stands of unequal volume change are grouped into the same block and are thus given the same time of harvest. The impact is particularly severe when blocks are enlarged to encompass many stands, and when the development of constituent stands per block is quite different. The worst case occurs, of course, when vigorously growing stands are configured into the same block with mature or overmature stands showing little, or negative, net growth. In this case, a single time of harvest for the block captures considerably less volume than that available had specific timing choices been tailored for each stand condition (e.g., an early harvest for the overmature stands and a much later harvest for vigorously growing stands).

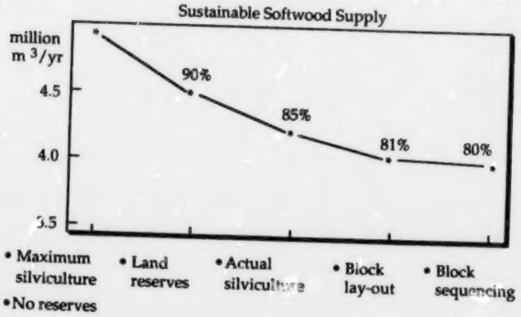


Figure 8. Factors that influence wood supply. See text for discussion.

The final step of block sequencing incurs little further volume reduction, amounting to only 1.5%. Block sequencing is performed to limit maximum openings to 125 ha and to maintain a minimum 5 year delay between the harvesting of adjacent blocks. The manner in which timber supply is affected by this step is analogous to that for block layout in that the harvest may be scheduled for a period other than that in which maximum volume is provided. The relatively modest impact of harvest timing choices at the block level results for two reasons. First, the 5 year adjacency delay is relatively short, and except in extreme cases of rapid block volume change, a 5 year change in harvest time does not significantly alter block volume availability given current stand yield forecasts. Second, by spatially aggregating stands in the block layout, the yield per block is stabilized somewhat and sensitivity to harvest timing per block is greatly reduced. It is interesting that an ill-conceived block layout, with little regard for selecting constituent stands per block, will create large harvest reductions due to blocking, but because it creates stable block yields, it will make timber supply insensitive to block sequencing. On the other hand, very fine blocking undertaken to maintain homogeneity of stand volume change within blocks will reduce the timber supply impact of block layout, but will create larger reductions in the block sequencing steps.

Implications to Management

Figure 8 shows that the steps taken in the planning process decrease the sustainable harvest from 4.85 to 3.9 million m^3/year. By isolating the contribution of each step to this reduction, it is possible to anticipate and plan for situations that may arise in the future. Figure 9 shows the factors that can be expected to change in the future, and that are likely to have negative effects on timber supplies.

First and foremost is the area in reserve. There is an increasing desire on the part of the public to hold more of the land base in reserve from harvest. Increased reserves will have a negative effect on timber supplies as

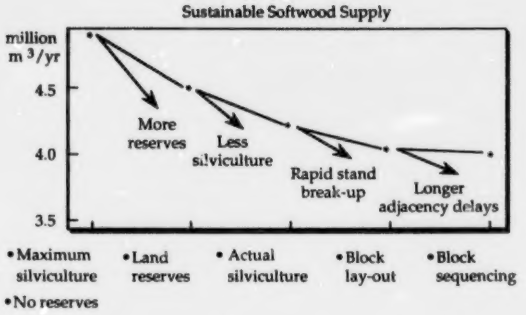


Figure 9. Factors that may reduce timber supply in the future.

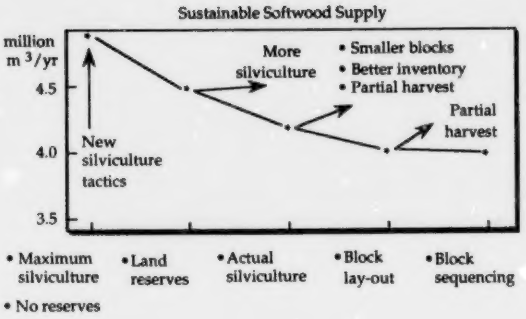


Figure 10. Factors that may increase wood supply in the future.

shown in Figure 9. The size of the impact will relate to the size and nature of the area withdrawn.

The second source of harvest reduction relates to reduced silviculture effort, which may occur if silviculture funding is curtailed. If silviculture funding becomes a victim of budgetary restraints, which is not inconceivable, wood supply reductions will be a direct result.

The third potential reduction stems from more rapid natural breakup of mature stands, which will increase volume losses incurred in operational block layout. Professional consensus in the province is that current yield forecasts underestimate the rate of softwood stand breakup and that softwood stand deterioration will accelerate beyond the forecast rates as the present 60-80 year age class matures.

The fourth negative influence on timber supplies will stem from protracted harvest block adjacency delay periods. There is a trend towards increasing the harvest delay between adjacent blocks to meet wildlife habitat requirements. These requirements will cause supply reductions incurred in the block sequencing process. The reductions due to block sequencing will be exacerbated if the more rapid stand breakup rates occur.

Assuming that rapid stand breakup does occur and that increased land reserves and protracted adjacency delays make sense to implement, the question becomes, What mitigating measures can be undertaken to offset the potential harvest reductions? Again, examining the components of the planning process is informative, and it reveals mitigating measures that may be available. First, the overall profile of harvest levels may be elevated by implementing a broader array of silviculture techniques (Figure 10). Recall that the present New Brunswick Crown land silviculture program is restricted to conventional planting and precommercial softwood stand spacing. Considerable opportunity exists to increase wood supplies by expanding silviculture tactics to include a broader range of treatments, including semicommercial and commercial thinning, mixedwood stand spacing, site improvement, and fill-planting. Implementing such programs represents a challenge to the forestry sector to develop the practices to physically implement these activities, to develop credible yield forecasts of stand response, and to enhance the forest inventory to help determine the abundance and location of areas suitable for each type of treatment.

The second opportunity to increase wood supplies is in the form of accelerated silviculture investment. Present funding captures only a portion of the silviculture opportunities and an expanded investment program can serve to offset some of the impending factors that will reduce wood supplies. In fact, it could be argued that any policies that remove land for nontimber uses contain explicit provisions for increased investment on the remainder of the land base. Such policies could facilitate land withdrawal decisions, without unduly compromising timber availability.

The third set of mitigating measures is effective at the block layout stage and includes (1) reducing harvest block size; (2) enhancing the inventory to better differentiate stands on the basis of volume change; and (3) introducing more extensive partial harvest programs. Smaller harvest blocks will better allow stands to be harvested at peak volume and will reduce the negative impact of blocking. This represents a considerable opportunity that could conservatively provide an additional 200 000 m^3 of annual harvest from New Brunswick Crown lands.

As a basis for finer, more judicious block layout, inventory enhancements are required to better characterize stands with respect to volume change. This could assist block layout decisions by better informing the block planner about which stands can be aggregated and harvested at the same time without incurring volume loss.

Introducing partial harvesting techniques creates a mechanism by which potential wood supply reductions can be offset in two ways. First, by removing only a component of the total stand volume, block layout impacts on wood supplies are dampened if partial harvesting takes impending mortality and leaves the vigorous individuals to continue volume accrual. Second, partial harvesting may lessen block sequencing impacts by leaving much of the stand overstory intact, thus maintaining required habitat conditions without the necessity of imposing long adjacency delay intervals between harvested areas.

Of course, there are numerous other factors that can have a negative impact on wood supplies and still other opportunities that can mitigate those effects. The specific list of problems and opportunities will vary with the forest in question. Regardless of the specific forest characteristics, thorough and systematic evaluation of the management planning process can reveal these problems and opportunities and provide guidance for effective response.

Summary

The substantial changes New Brunswick forest management has undergone in the 1980s will pale in contrast to those likely to occur in the 1990s as forest policy evolves, attitudes about forest values change, technology advances, and demands on the resource intensify and diversify. Recent New Brunswick experience has reinforced some general forest management planning principles that may help guide management through the challenges of the 1990s. The principles themselves are neither new nor particularly profound, but are probably more often pronounced than practiced. They are worth summarizing in conclusion here, not so much because New Brunswick's forest management began by adopting them as tenets of good management, but because they were practically demonstrated as such in the course of implementing the procedures discussed in this paper.

1. Forest management planning is a continuous process that should be practiced as such. Its goal should extend beyond the design of management strategies to include identifying limitations to forest management, particularly those with respect to resource information, information management, forest practices, and forest policy. These limitations provide useful and meaningful guidance for conducting research and development activities.
2. The management planning cycle provides the opportunity to operationally introduce those research and development advances that can relax the limitations in management capabilities. Introduction of such advances at each cycle provides for continual and systematic improvement in the overall management process.
3. Forest management activities are inescapably based on forecasts and, thus, are attendant upon a high degree of uncertainty. The issue is not whether the forecasts will be wrong, but by how much they might be wrong and why. Incorporation of an effective monitoring system in the management process is necessary to provide the answers and to allow reconciliation between what is expected to happen and what actually happens.
4. There is an important relationship between strategic and operational planning in forest management. Forest development forecasts used to design management strategies should reflect the true nature of practices in the forest. As such, they require explicit inclusion of operational and environmental realities. By the same token, operations are merely the means to implement a strategy; thus, they should be formulated and conducted within the context of the management strategy itself. The relationship between strategic and operational planning has been properly maintained when the short-term operating plan is a clearly defined subset of the long-term management plan.
5. Management planning is much more than the development of management plans. Thorough forest development analysis can reveal impending management problems and potential management opportunities if it is carried past the stage of merely setting harvest levels and silviculture programs. Early anticipation of these problems and opportunities is essential to provide the lead time necessary for research and development to formulate appropriate actions.

4. Harvesting, Timber Losses, and Changes in the Land Base

Withdrawals of Capital

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Abstract

Withdrawals from forest capital can include changes in land use designation, such as land set aside for parks, or depletion of wood volume as a result of harvesting, fire, or insect and disease infestations. The effect of some timber management reserves, e.g., wildlife reserves, may also be equivalent to land base withdrawals. Current public debates surrounding the use of forestland, the rate of harvest, and preservation of old growth all require better information to support decision-making. A national forest data base on withdrawals is needed, but it should be designed to use current provincial and federal inventory data, rather than starting over with a new system. A number of recommendations are made with respect to estimating growth losses due to fire, insects, and disease; the need for more timely inventory updating; and the need for new information systems combining data bases with geographic information systems.

Résumé

Parmi les retraits de capital forestier, mentionnons les modifications de la catégories d'utilisation des terres, comme la création d'un parc, la disparition d'un volume de matière ligneuse causée par la récolte, le feu, les insectes ou les maladies. La création de réserves, comme des réserves fauniques, peut également avoir un effet similaire à des retraits de terres. Les actuels débats publics relatifs à l'utilisation des terrains forestiers, au rythme d'exploitation et à la préservation des vieilles forêts exigent tous de meilleures informations à l'appui de la prise de décisions. Il faut se doter d'une base nationale de données sur les retraits de ressources forestières; elle devrait être mise au point à partir des données provinciales et fédérales actuelles d'inventaire plutôt que d'un tout nouveau système. L'auteur formule un certain nombre de recommandations sur l'estimation des pertes de croissance attribuables aux incendies, aux insectes et aux maladies, sur la nécessité de mettre à jour en temps plus opportun les données d'inventaire ainsi que sur le besoin de nouveaux systèmes d'information combinant des bases de données à des systèmes d'information géographique.

Introduction

Webster defines a withdrawal as "the act of taking back or away something that has been granted or possessed." A simple enough definition, but depending on whether you see through the eyes of a major forest industry stakeholder or through the eyes of a growing number of other stakeholders, such as those tied to Indian treaties, the notion of grantee and possessor is a moving target indeed. *Forest inventory terms in Canada*, 3rd edition, defines withdrawals as "areas removed from the forest land base." This too seems quite clear, but when the potential for change over time is considered, the notion of removal can take on varying degrees of permanency.

The *Financial Post* printed an interesting editorial on May 14, 1990 stating that Canada "is losing productive forest at an unsustainable rate." This statement was followed by the assertion that "more than 25 million hectares now lying fallow were once productive forest. Between 25% and 50% of the 777,000 hectares cut down each year do not grow back or go into noncommercial use. Fires destroy a million hectares a year and pollution is threatening many more." With respect to these statements, what really twigged me in the context of this paper is the underlying assumptions implicit in such notions as

- defining tomorrow's noncommercial forest in today's terms
- total destruction by fires
- the threat of pollution

What should we in the forestry community be talking about when we refer to withdrawals of capital from the forest estate? Should we be describing depletions of timber resulting from harvest, fire, insects, and disease? Should we be referring to the permanent and semipermanent reductions in availability of the forest resource for industrial use that arise from land use decisions related to urbanization, agriculture, the building of permanent roads, and designations of parkland and wildlife reserves?

I believe we need to discuss both, and in this paper I will make a distinction between withdrawals from the forestland base and depletions of the growing stock on that land base.

Withdrawals and Depletions: A Wide-ranging Issue

In the short term, the impact of both withdrawals and depletions is to limit the availability of timber for harvesting. We must ask ourselves, therefore, Will today's scenarios replicate themselves into tomorrow's reality? Forest management is a long-term business that relies on our ability to predict both the productivity of the land base and what, in fact, the future forestland base will be.

Because of the need for long-term planning, the size of the land base we manage, and the complexity of interacting pressures on that land base, our information requirements are staggering. The former Ontario Minister of Natural Resources, Lyn McLeod, emphasized that one of the building blocks for future program development is improved information and knowledge. Along with that we need better analysis of data and information about the forest and its ecosystems than we have at present.

Not only do we need to measure the impact of our own actions and decisions on the forest but we also need to monitor and measure the effect of societal trends and changing expectations. For example, during our generation, the population of the Earth will double. Not only will that be challenging for the forest industry, in terms of demands for products, but it will also place enormous pressures on the land base to provide for food, shelter, urban infrastructure, and recreational pursuits. When we add society's mounting concern over the environment, it is evident that the policymakers of the future face difficult decisions concerning the availability of land for timber production.

How do we factor these trends into making long-term wood supply projections? How we deal with withdrawals and depletions is directly related to this question. The forestland base presents us with a number of unknowns. We are accustomed to working with the old forest and we know with a degree of confidence what we can expect to harvest and how much we may expect to lose to fire, insects, and disease; however, our ability to predict impacts related to other values, such as wildlife habitat and outdoor recreation, is only emerging.

As we move toward the year 2050 in our long-range plans, we will be working more and more with the new forest - a forest that is new not only because it is young but also because it is new to us. As we begin to rely on the new forest to provide us with the benefits society has come to expect, forest managers will have to predict the availability of timber with more accuracy than ever before so that capital investment by industry will be made based on reliable commitments in a world of ever increasing competitiveness.

Hopefully, these illustrations help us focus on the wide-ranging issues that the question of withdrawals and depletions can impact upon. Whether we like it or not, the business of resource management has become everyone's business. Timber planning processes across the country are being challenged and changed by the growing public concern for environmental issues, such as ecosystem preservation. That is today's reality, and to make matters "interesting," the media seems to be out of touch with the genuine efforts we are making to meet that reality. For example, we continue to see headlines that glamourize the "effects" of clear-cuts. In the words of Hal Holden in a recent article "these half truths tell us as much about the reality of what is happening to our forests as ugly ducklings tell as about swans!" Mr. Holden goes on, with reference to clear-cuts and society's outlook, to say that "short-term visual pain for long-term gain finds little favour in an age where desire for instant gratification shapes many of our values." I think he's right and I think it's unfortunate that the short-term "visual pain" issue results in "withdrawal overkill" in many instances. How do we bring reason to the decision process in times of such heated debate?

In Ontario, environmental assessment hearings on timber management have been under way for 2 years, and will create a new set of directions for managing Ontario's forest resource - directions that will almost certainly require us to consider new and largely unmeasured influences on the forestland base and the forest industry. These directions will further reinforce the commitment to sustainable development that our government shares with a growing number of other governments and industries around the world. Very simply, sustainable development in forestry means managing forests to endure social, economic, and environmental benefits. It means meeting the needs of today's society without compromising the ability of future generations to meet their needs - without, in other words, closing the options of our children and grandchildren.

Many foresters are surprised to find the public hailing this latest notion as a new concept as, in reality, it is one that grows naturally from our long-standing commitment to sustained yield and comprehensive timber management planning.

Nevertheless, the vigour of a commitment to sustainable development brings with it an enhanced need for reliable information - information that will increase our ability to make predictions. In Ontario, this broad-based, wholistic concept of forest management is leading to the development of a new forest policy framework in which all forest values will be included. One set of objectives will flow from this framework to embrace all users of the forest. Within this umbrella will be initiatives ranging from expanded public involvement in decision-making to managing for old growth and the development of a new forest production policy.

Whether we are dealing with highly visible issues like old growth pine or with the more routine withdrawal questions that must be answered, if we are to manage our forests in a consistent manner, the key requirement is information. When reliable and current information on all values of the forestland base is available, we will have the basis to predict the effects of withdrawals and depletions.

Traditionally, withdrawals have included such things as agricultural, mining, and cottage developments; permanent roads; ecological reserves; parks; and critical fisheries and wildlife reserves; whereas depletions have included harvesting and losses to fire and forest pests.

How many trees are being cut? How much forest is being destroyed by fire; how much volume does that represent? How much timberland is being designated as wildlife reserves? Answers to these questions have been difficult enough to arrive at in the past because of an inability to map and document on a timely basis; the need to project future withdrawals to address the issue of sustainability, and the need to include a new generation of forest removals growing from the public's concern over environmental issues, will make calculations and documentation even more difficult, particularly when we consider that many of these removals may not, in fact, be permanent.

The decision to withdraw wildlife habitats from the forestland base, for example, is based on the current state of the forest, current population levels of wildlife species, and current values held by the public and resource management decision-makers. Any of these variables may change - some most certainly will. Does that mean that a reserve set aside for the spotted owl this year may be returned to production when the forest stand, through natural evolution, is no longer preferred by the owl? By that time, perhaps, it may have become the preferred habitat of some other species requiring protection.

There is no doubt that we will have to take into account current and future hard-to-measure variables, e.g., the need for green spaces, the need to protect endangered species, the need for scenic vistas, wildlife range values, critical wildlife habitat, old growth preservation, and ecosystem diversity, along with economic variables, such as employment opportunities; the list could go on, and will unquestionably continue to grow. This fact emphasizes the need to involve all users of the forest in setting priorities and specifying long-term sustainable objectives for all forest values while recognizing that the goal is to balance and rationalize the multiple uses of a land base that is under extraordinary pressure to be all things to all people.

Timber has traditionally been looked upon by foresters as the primary forest value - everything else has been a "constraint." We must "turn those constraints into opportunities" for good forest management. Only when the concept of sustainability is applied to all values will we be able to put the Temagami's and the South Moresby's into the context of a long-term forest policy. No amount of rationalizing and priority setting will help us meet these challenges without an accurate data base that includes the current state of the resource and reliable predictions about the long-term effects of both traditional and newer sources of withdrawals. That is the bottom line if we are to make responsible short-term decisions at the management level, as well as wise long-term decisions for sustainable development at the strategic planning and policy development level.

We will have to determine the extent to which the withdrawals are mutually exclusive or overlapping, and whether they are permanent or temporary. To return to our spotted owl, which could easily have been a moose, we will have to make long-term assumptions on which we rely to sustain such wildlife populations.

If we can't make predictions, long-term planning will be ineffective. If we learn to make predictions well, our management processes will allow for more efficient transitions from one land use to another - and newspaper headlines announcing the permanent loss of jobs to save an endangered species should become a thing of the past.

We must find ways to incorporate timber harvesting feasibility criteria into our integrated resource management (IRM) decision-making process. We do this now when harvesting prescriptions call for leave blocks and return cuts, but we don't pay enough attention to this fundamental factor when decisions are made to establish reserves to protect nontimber values. Industry's input is essential to developing criteria that will give credibility to predictions of future timber availability from such areas. Some of the parameters are

- size of area
- merchantability of timber
- configuration of the area

Before we become completely daunted by the information requirements facing us, let's look at where we are now. Industry, together with provincial and federal governments, cooperates in the collection of information on depletions. Our most accurate records of depletions are those on harvesting. We keep volume records of sales of Crown timber through our scaling and billing systems, and in Ontario, for example, we require all mills to report annually the amount of roundwood they consume from all sources. Problems with the information gathered arise primarily when attempts are made to tie depletions back to the land base. The difficulties result from complicated wood flow patterns, large reporting areas, and varying merchantability and utilization factors.

Our information on harvests from private land, which yields some 20% of Ontario's annual harvest, is also limited. Because we are rarely involved in the sale of wood from private land, we are completely reliant on the mill reporting system for collecting volume information on wood originating from private land. Of course, this doesn't track nonindustrial private wood consumption; information on this is obtained from Statistics Canada and special surveys.

We also track harvest depletions on an area basis through an independent reporting mechanism. Harvest depletion reports classified by age class and species are submitted annually for each management unit. Again, private lands are a problem as only the small portion of private forestlands that are harvested with government advisory assistance can be tracked under this system. We also record the area of partial harvesting. However, this information is difficult to analyze to determine implications to potential wood supplies because leave periods and harvesting intensities vary dramatically.

With respect to utilization, when an area of land is documented as cutover, a considerable amount of potentially merchantable wood may be left standing as residuals, i.e., trees that may be valuable in the future for another industrial application or for another forest use. These residuals are standing on "depleted" land according to our records, but, in fact, they can represent a potential future value.

With an abundance of overmature timber available for harvesting, and with the acceleration of many harvests to minimize losses to mortality, other land use commitments often appear insignificant. However, it is predictable that increasing commitments to other land use values, combined with normalized harvest schedules as we begin to move into the new forest, will have a measurable impact on available wood supplies. We will not know the extent of this impact until we can accurately predict the volumes we will realize from the new forest. There is a strong dependency here on our efforts to develop better growth and yield information.

When data about any type of reserve area are gathered, it must be remembered that land area is not necessarily correlated with volume. For example, depending on the location, a wildlife reserve may account for 5% of the land area and represent 10% of the volume, or vice versa. Managers of the forest estate need access to volume data as well as area data.

Removing designated areas from the land base requires an active decision by forest managers and society as a whole. These decisions, complex as they are, can be considered, evaluated, and even reversed. Harvest activity, although not a withdrawal according to our definition, is a depletion that is under our control as managers of the forestland base.

Beyond our immediate control, yet critically important in terms of our data base, are depletions due to fire, forest insects, and diseases. Even though these depletions raise issues of measurement and predictability that differ from those of harvest or reserve allocation, models are needed that will allow us to account for and schedule them as we do harvest depletions.

Although it is common to incorporate fire losses as an area withdrawal, they realistically represent a volume depletion. Losses resulting from fire represent a major capital depletion that is equivalent to harvest over the long term. Although measurement of the area lost to fire is relatively reliable, it is of limited value in determining the volume lost. It is also of limited value as a predictor due to the random nature of wildfire, which may burn previously burned areas and does not distribute itself evenly over age-class structures or site classes. It is difficult to measure the impact of a burn in the first year as pockets of undamaged timber may remain and some areas may partially recover. Thus, the inventory has been modified rather than totally depleted.

In Ontario, fire is currently recorded as a depletion by area, working group, and age class. Although burned areas are recorded and mapped annually, information about volumes, working groups, and age distributions are only updated on a 5 year schedule. Even though predictions of the area lost to fire may be off this year or next year, or even for the next 5 years, they will likely become reliable as we look at whole rotations; we can't say the same for volume predictions and we need to improve this aspect of our fire prediction modelling.

Another important aspect of fire depletions is our limited knowledge about the long-term effects of fire on certain sites. Although few studies have investigated long-term nutrient losses on fire sites, and erosion problems are rare where a standing forest has been burned, there is concern that extremely intense fires, like some experienced in northwestern Ontario over the last decade, may lead to long-term changes in site quality (e.g., areas with thin soil). Thus, to project timber supplies over the long term, a better understanding of the effect of fire on site productivity is needed.

The task of estimating pest losses is complicated by extensive occurrence, our limited understanding of the cause and effect relationships that govern losses, and overlapping conditions within forest stands. Accurate information on natural mortality rates and vast surveys of infestations are required to estimate growth and mortality losses arising from pests.

Provinces rely heavily on the Forest Insect and Disease Survey (FIDS) of Forestry Canada to collect information on pest incidence. Areas of pest and insect infestation are mapped by aerial surveys, ground plots are established in areas of moderate to severe defoliation, and incidence and mortality rates are assessed. Losses are then calculated by extrapolating mortality rates to areas mapped based on host availability.

In Ontario, the analysis to determine losses for the period 1982-1987 has just been completed. For this period, Ontario forest inventory staff worked with Ontario FIDS staff to develop the procedures required to incorporate impact models with the inventory data base to enable predictions of both volume loss and mortality.

Losses to pests are immense. From the last report, covering the period 1977-1981, we found total losses approximately equal to the volume harvested, with roughly two thirds of the volume losses going to disease and one third to insects.

Our approach to considering pest losses in wood supply projections is also just evolving. Possibly, some of these losses are inherent in the empirical yield curves; however, in the case of severe and persistent infestations, such as the spruce budworm, special considerations may be warranted. Once we can effectively collect data on losses due to fire and forest pests, how do we use this information to predict the effects on both short-term and long-term wood supplies? Although we may be able to average losses over the long term, impacts on short-term allocation can be critical.

We must also factor in other losses, two of the most important being blowdown and inoperability. Tracking losses due to inoperability is especially important because many areas can become operable as a result of demands for new species or the evolution of new technologies. Of course, industry's input in this area is essential.

Private land is a portion of the forestland base for which withdrawals are difficult to predict. In Ontario, for example, where 90% of the forest is Crown, private land forests account for a harvest of about 5 million m^3 per year, compared with about 21 million m^3 for Crown forests. Future ratios are difficult to predict, however. Census figures from the Department of Agriculture show a dramatic drop in the acreage held in farm woodlots over the last 40 years, and recent surveys suggest that the number of private landowners willing to see timber removed from their property is decreasing.

In Ontario, we are even finding that some landowners who have planted trees under the Woodlands Improvement Act program are indicating that they would rather not have timber harvested from their lands. Thus, the whole question of withdrawals as it relates to private land forests is an important issue, one that seriously affects our ability to predict timber supply futures with any degree of accuracy.

As we commit the necessary resources to developing a national data base, it is essential, up front, that we assess the public's needs and clearly define the data sets required to satisfy objectives? What are these objectives? In addition to recording biological data, such as numbers and types of trees, data related to the forest industry and economic outlooks must be collected. Also, how do we factor in useful information for nontimber values?

We need to minimize duplication of effort in what promises to be a very expensive undertaking at a time of severe constraints. We should not develop the data base in a vacuum; we must be outward looking and explore the experience of others. Scandinavian countries, such as Finland and Sweden, for example, have a national data base model that works well for them, but in making comparisons, it must be remembered that their inventory system conforms with their administrative system, which is nationally based. It is also important to note that their land base is more than 50% privately owned and predictability of landowner attitudes is not an issue given their policy structure and co-op management mechanisms. Perhaps we should look more closely at experience in the United States. Certainly, the United States should have considerable experience in modelling the availability of wood from all forestlands and aggregating useful data at the national level.

In Canada, the federal government administers forestlands in the territories, on Indian lands, in national parks, and on other federal lands, while the provinces manage the vast majority of the country's forestland base. Each has it's own inventory system that addresses particular administrative and management needs. These inventory systems are structured to support forest management and their usefulness is related to their accessibility and their ability to be updated and applied to the management tasks at hand. In Canada, these management tasks are carried out, by and large, at the provincial level.

I hope we are not assuming that a national data base is to be superimposed on that system. Rather, that we are looking for ways to share the existing inventories of all of the provinces, as well as that now used by Forestry Canada, to produce a useful national picture. Before this can be accomplished, however, we must be clear on the intended use of data aggregated at the national level. As a priority, I would submit that this aggregation must be understandable at the layman's level. If it isn't, the effort will have been for nought, for "today's reality," as discussed earlier, must give us our priority direction. As well, this initiative should be a comanagement venture with industry to ensure that the information portrayed is realistic in terms of the marketplace.

Recommendations

To zero in on the issues, I would like to summarize with emphasis on the future:

- With respect to fire losses, the greatest problem is accounting for them in wood supply analyses.

Although it is common to incorporate fire losses as an area withdrawal, they realistically represent volume depletions. We must develop fire prediction models that use volume as the bottom line. If we don't have this ability, serious discrepancies between actual and predicted timber supplies will result.

- Beyond the issue of accurate and precise estimations of losses to fire and pests, we must put this information to good use in evaluating protection programs. These efforts will be crucial to timber volume availability on an ever increasing level as we wind down the old forest.
- We have to pay more attention to the uncertainties of private land. We must have up-to-date information on landowner attitudes and potential landowner response to different policies and socioeconomic conditions to help us predict future timber supplies from private land.
- If we are to become adaptive managers, we need sustainable development objectives for all uses of the forest based on good inventory information and reliable data about the carrying capacity of the land to meet these objectives and we need to develop the modelling tools that factor this information into our wood supply forecasts.
- We need regular inventory updating. In Ontario, we are developing systems that, when fully operational, will allow updating to take place at the user level whenever new information is available. The priority is better volumetric projections.
- We need comprehensive growth and yield information as well as knowledge of stand dynamics, with particular reference to the new forest, if we are to adequately account for today's decisions on other forest uses in our predictions of future timber supplies.
- We need decision support systems that incorporate forest information with new technologies, such as geographic information systems, i.e., systems with the capacity to integrate all forest values, thereby assisting us in tracking impacts on timber volume availability.
- We must use our records of other significant losses, such as blowdown, wisely to identify susceptible areas and include factors of risk in our decision processes.
- We must keep the scale of depletions and withdrawals in mind when developing forest policy because, apart from harvest, total withdrawals and depletions under today's management systems may exceed 30% in some areas.
- We must develop more efficient ties between all of these depletions and withdrawals and inventory updating procedures so that we have reliable information on a continuous basis to support timber supply projections.
- We must work closely with industry to ensure that we can predict the volume impact of inoperable areas and to factor timber harvesting criteria into our decision process related to both planned leave blocks and other areas that have potential for a return cut.

Finally, I would point out that we in Canada operate in a global marketplace where the pace of change is rapid. Changes in mill processing and timber harvesting technology geared towards the utilization of whole tree fibre and yesterday's weed species are coming on stream out of necessity. In Ontario, for example, where the softwood/hardwood roundwood consumption ratio was 14:1 in the 1950s, it is now 4:1 and we predict it will be 2:1 before the year 2000. That's a dramatic shift and we have to learn how to predict the impact of the underlying technological changes so we can make the right decisions today about future timber supply needs.

As well, transportation economics will be quite different in the new forest after we've extended road networks throughout the old forest. As this change occurs, currently underutilized fibre, including potential early thinnings, fire charred wood, and that portion of the gross timber volume now left behind, will gradually become part of the supply base. To account for these trends and the foregoing issues in our inventory updating and timber supply modelling is a challenge we must face because today's withdrawals and depletions will become many of tomorrow's opportunities.

Timber Harvest Statistics: Past Practice and Present Needs

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Abstract

Use of Canada's forests for industrial fibre and recreation is increasing. Public concern about the management of the nation's forests is increasing as public values and objectives change. Current forest data provide information for both public and industry on the state of the forest, but present data are not adequate for modern needs. Information on volumes harvested, annual allowable cuts, growth and yield, and areas harvested and regenerated needs to be improved to satisfy forest managers' and the public's questions on the state of the resource. Coordinated, energetic action by industry, provincial governments, and Forestry Canada is required. These data should be part of a national analysis and report to Parliament on the forest resource compiled by Forestry Canada at 5 or 10 year intervals.

Résumé

L'utilisation des forêts canadiennes comme source de fibre industrielle et lieux de récréation croît. À mesure que les valeurs et les objectifs de la population évoluent, le souci que l'on se fait au sujet de la gestion de nos forêts se précise. Les données forestières actuelles informent le public et l'industrie, mais de manière peu moderne. Pour leur fournir des renseignements à jour, il est nécessaire d'améliorer les données sur les volumes récoltés, la possibilité annuelle, la croissance et le rendement, et les superficies des terrains récoltés et régénérés. À cette fin, il faut que l'industrie, les gouvernements provinciaux et Forêts Canada fassent preuve de collaboration et y consacrent leurs énergies. Ces donnés devraient mener à une analyse nationale sur la ressource forestière que compilerait Forêts Canada tous les cinq ou 10 ans à l'intention du Parlement.

Introduction

This paper discusses the current state of forestry information. From the outset, it should be made clear that there is a big difference between data and information. Artists use paint to produce a picture. Data are used in the same way to produce information. A good picture requires the right paint and it must be skillfully applied. I am not a forest statistician or economist. I do not work with forest data on a continual basis. I do use forest data to develop information for use in two areas.

- Broadbrush strategic planning and assessment of our situation in terms of international supply of and demand for forest products
- The development of information for use in public information programs in Canada and in response to questions from abroad

Comments made in this paper imply no criticism of any individuals involved in the process of gathering and analyzing data. The people involved in this process are conscientious and do their best to do a good job. They have to work within a system that is not good enough to meet today's needs.

There are three main reasons for developing a sense of urgency about forest data and information. First, the management of Canada's forests is a matter of considerable public concern. Second, forests are the basis for very significant economic activity - both industrial and recreational. Third, we are using the forest much more intensively than we have in the past, and we must know much more accurately how our use relates to the capacity of the forest to sustain those uses.

Public Concern

The public does not think that we are doing a good job of managing, harvesting, and regenerating the forest. The public is on the verge of giving us a failing mark. Scott Wallinger of Westvaco gave a useful message to the American Pulpwood Association in April 1990. Speaking about industrial forest practices in the United States, he said that industry is doing the same things now that it has done for the past 10-15 years. What has changed are the values that the public uses to judge forest practices. He stated that industry must change to stay in step with the owners of the forest and ensure that woodlands operations meet public objectives.

We don't have only Canadian public opinion to consider. We trade with the world. We are the largest single supplier of forest products to world export trade, approximately 23%. This industry provides some 275 000 direct jobs, $30 billion in shipments, and $20 billion in net exports.

In 1988, a report was prepared for Forestry Canada on Canada's forest inventory over the next 20 years (Woodbridge, Reed and Associates 1989). This report indicated a doubling of world demand for forest products between 1985 and 2010. The year 2010 is only 20 years from now.

However, people in Europe are questioning whether they want to buy forest products from countries that do not practice sustainable development. They are looking very hard at the management of tropical hardwood forests. Some nontariff trade barriers have already been put in place. It is only a small step to become equally concerned about northern softwoods.

Their concern is driven by worry about the environment and the health of the world. However, we can expect that this growing concern will be fertilized and cultivated by those who have very different ideas about the true vocation of our forests.

In the July 15, 1989 issue of the *Economist*, a paragraph of the lead editorial on the G-7 "Green Summit" of 1989 stated, "The summiteers can easily have a quiet word with each other about some small points: such as the fact that Japan, the biggest importer of tropical timber, needs to ensure that it buys only wood that is managed in a sustainable way."

We have been reliably informed that forests will be high on the agenda of the G-7 meeting to be held in Houston, Texas, during the summer of 1991. Don't think for an instant that there will be no trade implications flowing from this discussion.

The Canadian public and our customers in many parts of the world expect us to practice sustainable development. Some say that sustainable development is a buzzword. I don't believe that. I believe that it is a concept that has seized the minds of many of the public and of farsighted leaders of government and industry all over the Western world. It offers a middle path between "mindless economic growth" and "turning out the lights." To walk this path successfully, we must become better forest managers in every sense of the word.

Data

We must ensure that our data and information on all aspects of forest management are timely, honest, complete, correctly interpreted, available to all who wish to use it, and show a picture of a well-managed forest. According to Joe O'Neill of Miramichi Pulp and Paper in New Brunswick, the essential component is to have impressive woodlands operations that we will be proud to show to the public wherever they may be. The data we collect, analyze, and transform into information for forest managers and the public tell the story of our management - its successes and failures - and they are at least in part the basis for the public's judgement on our stewardship of the resource.

With this as background, national data on roundwood harvest will be examined.

The following topics will be dealt with briefly:

- Gathering data
- Aggregation
- Results
- What do we need?

These topics will be discussed using three measures of the harvest that appeal not only to foresters but are also suitable for use in public information programs. They answer questions about the management of our forests, they relate to sustainable development, and they are easily understood.

Harvest volumes alone are not enough because everyone asks, Compared with what? The three measures used here are

- Volume harvested versus annual allowable cut (AAC)
- Volume harvested versus annual growth
- Area harvested versus regeneration efforts

Volume Harvested Versus Annual Allowable Cut

Figure 1 illustrates total harvest versus AAC, Figure 2 shows hardwood harvest versus AAC, and Figure 3 presents softwood harvest versus AAC.

There are several components to the harvest volumes compiled by Statistics Canada. Volumes harvested on Crown lands are measured, compiled, and reported to Statistics Canada by provincial governments. Volumes harvested on private lands are estimated based on figures from previous years, which are revised based on the general level of activity in the forest sector.

This is the only way these volumes can be determined at present, and the system is fairly sound if the private land volumes at some point were known, so that revisions could start from some bench mark. Current Statistics Canada staff who are responsible for developing these data do not know how or when this bench mark was established. Furthermore, the system is acceptable only if there are no policy or economic changes that would influence the volumes of wood cut on private lands. Quebec and New Brunswick have both changed policies drastically over the last 5 years or so. As it is, 79% of these harvest volumes comes from Crown lands and the numbers are fairly certain, but we are estimating 21% of the nation's harvest. For this reason, I don't feel very comfortable with these figures.

Annual allowable cut is more complex. Calculations are based on an up-to-date, accurate forest inventory. The question is, How many provinces have one? The Association of British Columbia Professional Foresters called for a new forest inventory in British Columbia at their annual meeting in February 1990. G. Baskerville commented on the Ontario Forest Resource Inventory (FRI) in his audit report on forestry in Ontario, and in my view condemned it with faint praise. Industry people tell me that it is fine for the "big

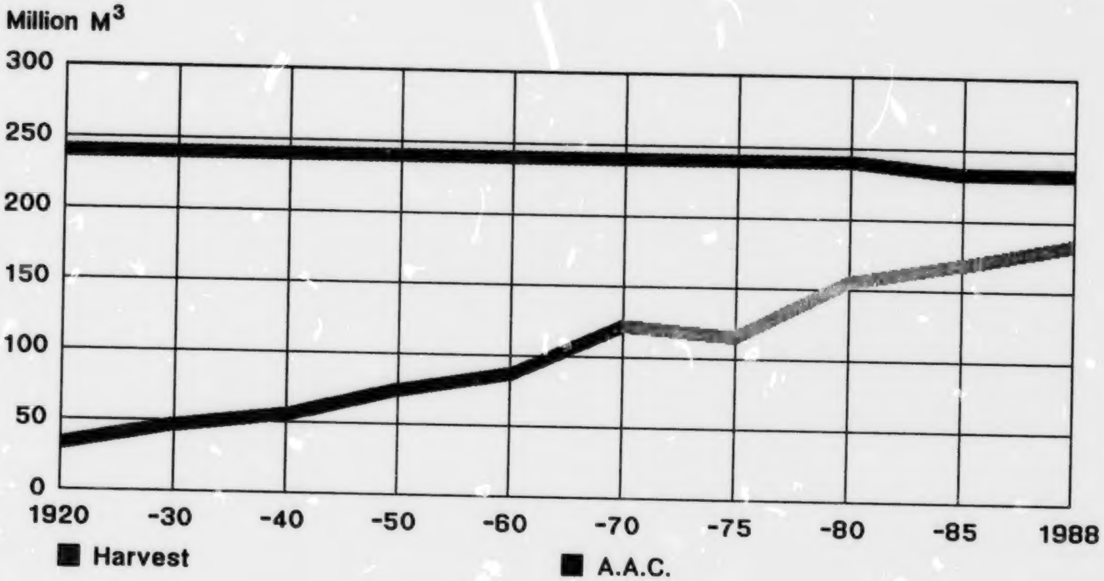

Figure 1. Total harvest versus annual allowable cut.

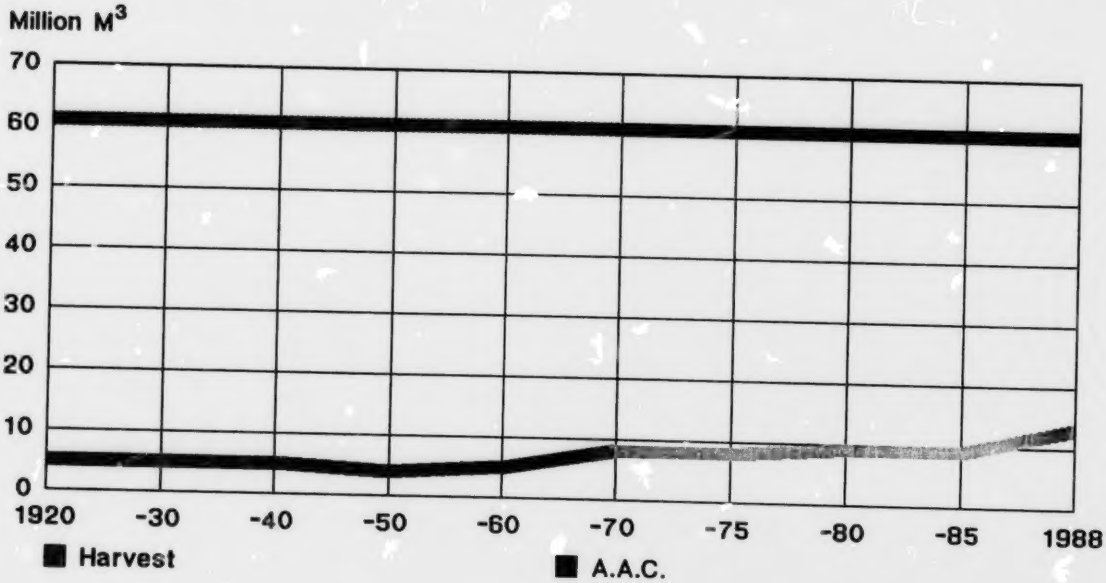

Figure 2. Hardwood harvest versus annual allowable cut.

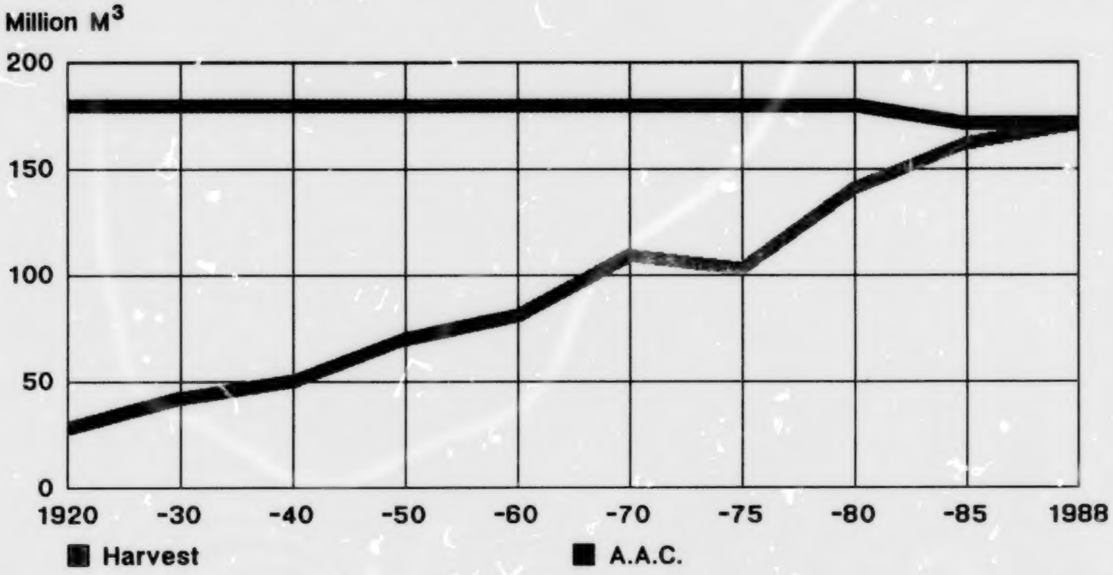

Figure 3. Softwood harvest versus annual allowable cut.

numbers," on large management units, but not good enough for management work and planning.

Viewed from an industrial perspective, I believe that we must look very hard at our provincial inventories.

- When were they planned?
- When were they conducted?
- Do the plan and the data meet modern needs?
- Are all commercial species included?

We cannot move with confidence and public support unless our plans are based on excellent information.

Annual allowable cuts are also based on

- Good analysis of economic accessibility. As we all know, this is a moving target.
- Accurate rate of growth data that are valid for all types and ages of stands within the inventoried area.
- Up-to-date utilization factors. These change with economics and harvest systems.
- Allowances for losses due to fire, insects, and disease.

Back in the 1940s and 1950s, only 25-30% of the AAC was harvested. In 1988, the harvest was estimated to be almost 100% of the softwood AAC and 22% of the hardwood AAC. There is not much margin for error in the softwood.

Annual Harvest Versus Annual Growth

Another way to express harvest volumes is to compare annual harvest with annual growth. This is illustrated nicely in a graph presenting information from Sweden (Figure 4). I expect that it is accurate and contributes part of the answer to the questions

- Are we cutting too much wood?
- Are we planting enough trees?
- Are our forests well managed?

This information is produced from Sweden's National Forest Survey - a system of permanent sample plots. Why don't we produce a graph like this (Figure 4)? I believe that we cannot do so with the information we have. Perhaps we don't need to. It would take a substantial number of plots to provide us with a national figure. To provide solid information at the provincial level, as well as at the national level, would require several times as many plots. The cost would be high if such a survey was carried out by a national survey team, but it would be more reasonable if a protocol was drawn up covering the establishment and measurement of these plots, and if the cooperation of all forestland managers could be enlisted to establish and remeasure plots located in their areas.

Area Harvested Versus Regeneration Efforts

A third way to measure roundwood harvest that satisfies some of the concerns of the public and of the forest manager is to measure areas harvested and compare the results with the area regenerated (Figure 5). I believe

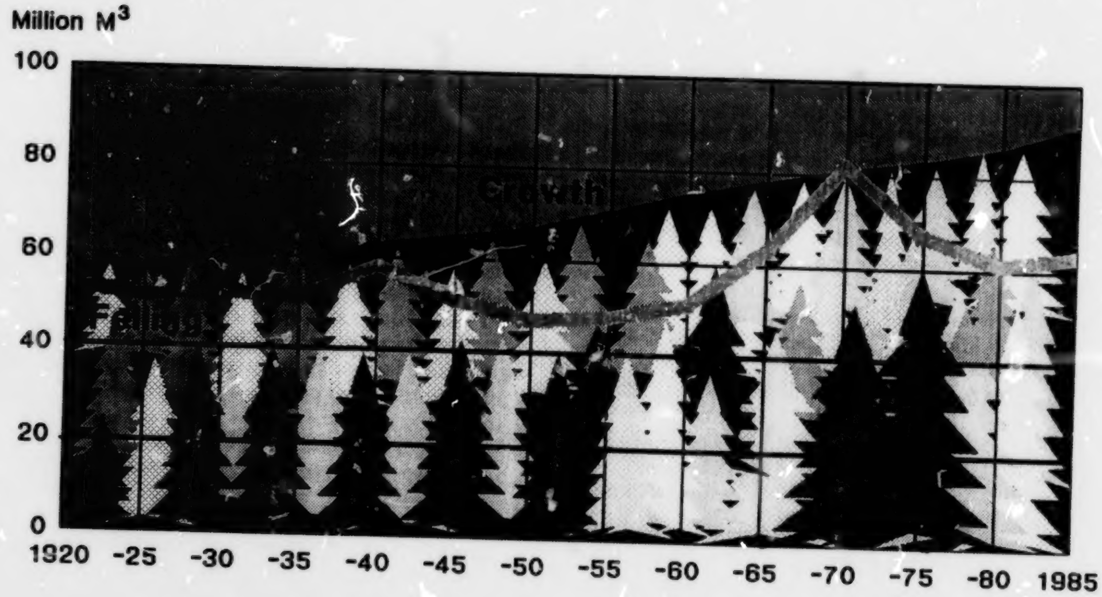

Figure 4. Annual forest growth and felling in Sweden.

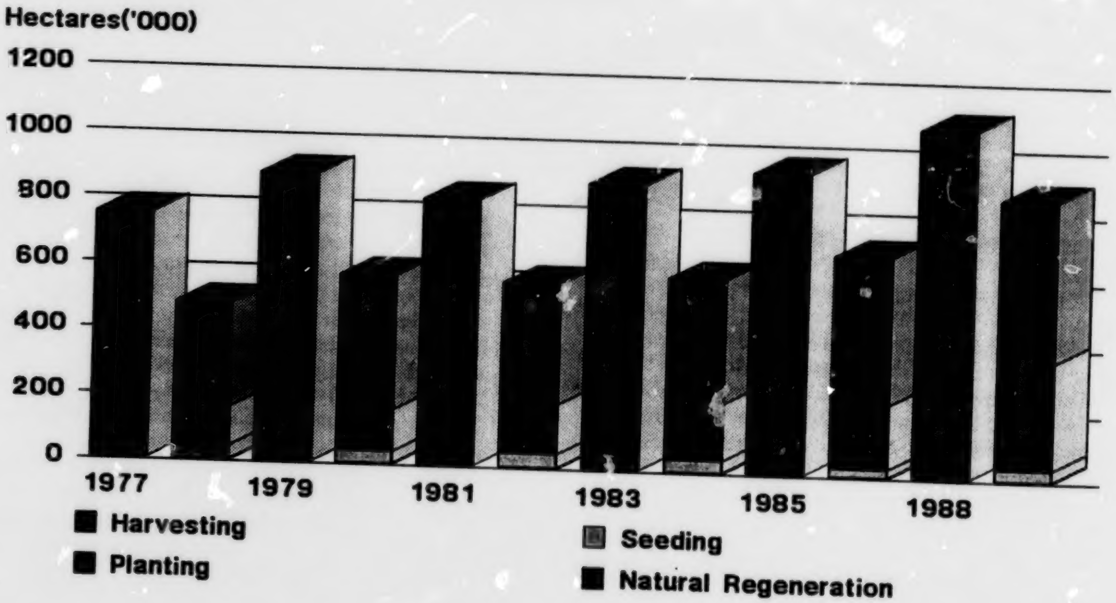

Figure 5. Area harvested versus reforestation efforts.

that we have a fairly good fix on the areas harvested, but a poor system to measure what happens to areas after harvest.

Regeneration is difficult to convey in graphic form because the process takes place over a period of 1-10 years. This year's planting program is on cutover areas from previous years, so current accounting is difficult. Natural regeneration surveys cover areas that were harvested 5-10 years ago. To apply these figures to last year's cutover is incorrect and inadequate, especially if harvest areas are increasing in size each year.

The data shown in Figure 5 are all reported by provincial governments. The regeneration effort includes direct seeding, planting (both of which have been reduced to account for expected failures), and natural regeneration.

The values shown in Figure 5 are a weighted average of the success of natural regeneration on areas left to be regenerated by that system. The rate is 50%. A 50% success rate is the historic success rate for spruce, pine, and true fir species across Canada.

Figure 5 presents data and the data are probably correct. Figure 5 does not, however, present information. Inclusion of these data in a widely distributed pamphlet produced by Forestry Canada and the Canadian Pulp and Paper Association turns the data into information because few foresters and none of the journalists and members of the public are able to judge the import of the explanatory text - if they read it at all. The data are inadequate for present needs because they do not include natural regeneration from any of the other major commercial species of conifers, such as western hemlock and Douglas fir. Nor do the data include any of the hardwoods.

If one looks at data from New Brunswick, which by coincidence has a spruce, pine, and true fir natural regeneration success rate of 50%, it will be observed that if all commercial species are considered, hardwood included, the average success rate for natural regeneration is 87% at reasonable stocking levels. Add to this data for seeding and planting, and a very different and much improved picture of New Brunswick's forest management is revealed. Perhaps I am misreading the impacts of these data. If so, they should be restated so that forestry generalists can understand them and develop a true understanding of what is going on in the woods.

There are basically three treatments that can be used to regenerate a cutover: natural regeneration, perhaps aided by scarification; direct seeding; or planting. Natural regeneration can only be called a treatment if there is a well-organized preharvest system to prescribe regeneration treatments. Otherwise, it really belongs in the category of "leftovers" and "let's hope for the best." If a preharvest silvicultural prescription system is in place and the regeneration success of all commercial species suited to the site is monitored, natural regeneration success ratios can be developed that will mean something.

Improvements

What do we need to improve things? Private and provincial Crown lands are separate problems, although they both contribute to our woodshed.

1. Both would benefit from the forest sector developing a sense of urgency about forest statistics and their importance.
2. Provincial governments must be committed to providing good statistics in a timely fashion. Provinces must not delay the delivery of figures to the national data pool until the provincial annual report has been printed.
3. We should all take a hard second look at the adequacy of our forest inventories to supply information for management in the 1990s. Do the inventories really correspond to the strategic planning needs of the province and the major industries that rely on the figures for long-term planning? A good forest inventory can prevent major public and financial embarrassment.
4. Do we have adequate growth and yield data to monitor the state of the resource and to calculate accurate AACs?
5. We must find a way to get a more accurate estimate of wood coming from private lands, both industrial and small private holdings.
6. Is the provincial inventory system providing adequate information on the state of the forest on nonindustrial private lands?
7. Should we establish a system of continuous forest inventory plots to be remeasured on a 5 or 10 year rolling interval to provide a continuous flow of information on the state of national and provincial forests? If such a system were set up and administered on a cooperative basis by all of the major players in the forest sector, it might not be as expensive as one would think.
8. The Canadian Council of Forest Ministers has agreed on a joint program to improve gathering and analyzing data. Forestry Canada is also required to report to Parliament on the state of the forest. If these two programs are well done in a timely fashion, it will go a long way toward solving the problem, provided, of course, that the base data is accurate and up-to-date.

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Forest Fire Statistics and the Timber Supply

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Abstract

This paper looks first at the kind of forest fire statistics that are currently available in Canada. The main statistics are number of fires, area burned, causes, and control costs. Good inventory data on burned areas are not available. The recent rising trend in national burned area is then presented, with its uncertain implications for the future. Next follows a comparison of two methods of portraying the impact of fire on timber supplies: (1) by a static accrual-depletion balance; and (2) by dynamic analysis of the interaction between harvesting and fire in a managed forest. These two approaches do not give the same result. The conclusion is drawn that modern dynamic analysis is necessary to clarify the impact of fire, and that the answer will be found in the timber output from the whole forest, not in the killed timber on the burned area. Some examples of simple dynamic simulation are presented, with implications for the optimum management strategy in a fire-prone forest.

Résumé

L'article présente d'abord le type de statistiques disponibles actuellement au Canada en matière d'incendies de forêt. Parmi les plus importantes des statistiques, on notera celles qui concernent le nombre d'incendies, les superficies brûlées, les causes et le coût de la lutte contre les incendies. Des données d'inventaire efficaces sur les superficies brûlées ne sont pas disponibles. En outre, on décrit l'augmentation récente des superficies brûlées au Canada ainsi que les répercussions incertaines dans l'avenir. Dans la partie qui suit, deux méthodes d'analyse sont comparées visant l'impact des incendies sur la réserve de bois : 1. une analyse statique de l'équilibre (pertes et gains), 2. une analyse dynamique en tenant compte des interactions qui se lient entre la récolte et l'incendie dans une forêt aménagée. Ces deux approches ne donnent pas le même résultat. On arrive à la conclusions qu'une analyse dynamique moderne est nécessaire d'éclairer l'impact des incendies et que la réponse se trouvera dans le rendement en bois provenant de la forêt entière et non dans le volume de bois détruit par le feu sur une superficie. Quelques exemples de simulation dynamique simple sont présentés ayant égard à la stratégie d'un aménagement optimal de la forêt menacée par le feu.

Introduction

Modern economic reality in Canada is that fire competes with industry for our forest's annual increment. There is also an ancient ecological reality operating quite apart from human affairs, namely that a large part of the forest has evolved to cycle at irregular intervals with lightning-caused fire as its agent of renewal. All of this is another story with respect to the present subject, but worth mentioning just to establish that fire is fought in Canada mainly for economic, not ecological or environmental, reasons.

From an economic viewpoint, then, one can easily imagine two broad purposes for collecting and compiling data on the incidence of forest fires in Canada. There is, for one, the desire to document the effect of fire on timber supplies and to determine, in both physical and economic senses, what can or should be done to limit this impact. There is, for another, the need for fire control agencies to document their physical performance, and to determine how best to allocate their budgets for maximum effectiveness in reducing the area burned annually. This paper begins with an account of the forest fire data currently available, plus a reference to the recent trend in weather and burned area. It continues with a discussion of the impact of fire on timber supplies and two different ways of measuring and interpreting this impact. It concludes with some suggestions for improving the collection of forest fire statistics and methods of analysis.

Current Fire Data

Desirable data for fire impact analyses include a map for each fire showing the boundaries and main unburned islands, good basic inventory data from each burned stand (age class, species, and timber volume), and data on the degree of damage or mortality. Until now, nearly all of this information, except area, has been missing. Both Bickerstaff et al. (1981) and Honer and Bickerstaff (1985) have made valiant attempts to account for fire in their analyses of Canada's timber balance, but they had to depend on informed assumptions to plug the gaps. Most jurisdictions do list burned area under three status classes, namely "merchantable timber," "regeneration plus immature," and "cutover plus other," but these have no real standing as inventory data.

From the earliest days of organized fire control in Canada, agencies have always collected forest fire data with their own interests in mind, namely in aid of their own operations. No one can fault them for this because to have compiled a complete inventory record as well would have been very expensive indeed. Accordingly, basic information currently collected for each recorded fire by all Canadian agencies includes the date, fire weather, location, and size. Secondary items recorded include the size of the control force and direct funds expended, cause, and status class as listed above. From this information, annual compilations are produced that include the following data:

- numbers of fires, by month and year
- area burned, by month and year
- numbers of fires and area burned, by cause
- area burned, by status class
- fire control expense, in terms of overhead and direct costs

The process for working up these statistics is as follows. The fire control agency in each major forestry jurisdiction first collects the data from its own operations. There are 14 such jurisdictions in Canada, namely 10 provincial, 2 territorial (Yukon and Northwest), and 2 federal (National Parks and Other Federal Lands). Each jurisdiction sends its information to Forestry Canada's Petawawa National Forestry Institute (PNFI), which acts as the main custodian of the nation's fire statistics. There, it is compiled, tabulated, and published by both individual jurisdictions and national totals. Running 10-year averages of many items are used for comparison with the recent past.

Historically, there were sporadic attempts to compile national forest fire data as early as 1908 (MacMillan 1909). Continuous records, however, date from 1918. The information was published in various ways over the years (e.g., Cameron 1923; Wright 1940; and Dominion Forest Service 1949). The information published by the Dominion Forest Service (1949) was the first of a series that lasted until 1969. More recent sources include Brady (1979), Clark (1983), and Ramsey and Higgins (1986), which covers the years 1981, 1982, and 1983. Some 20 individual years are missing from the public record, but the data are on file and available at PNFI. Statistics for the years 1984-1987 will be available soon (Ramsey and Higgins 1990), and good estimates for 1988 and 1989 are on hand.

The following are some approximate 10-year averages for the whole country as of 1989, based on a total forested area of 4.533 million km^2 (Forestry Canada 1988, Table 1).

Annual number of fires - 9500
  Proportion caused by lightning - 35%

Annual area burned - 2 000 000 ha[a]
  As a proportion of the whole forested area - 0.46%
  Proportion burned by lightning - 85%

[a]As smoothed exponentially by Van Wagner (1988).

These simple averages hide an immense amount of variation. The national burned area has ranged from 290 000 ha to 6 650 000 ha within the last 13 years, within a ratio of 23:1. The largest 3% of fires account for about 90% of the burned area, whereas two thirds of all fires are held to within 1 ha. The boreal forest sustains by far the largest amount of damage from fire, other forest regions accounting for a small fraction in both the proportional and absolute senses. The huge preponderance of fire caused by lightning compared with that caused by humans is also obvious from the above figures, giving rise to two impressions: first, that fire control agencies reduce significantly the area burned as a result of fires caused by humans that would otherwise not have been saved and, second, that nature, in the form of lightning, still exerts the major influence. Finally, the annual pattern in any given province or territory may bear little or no resemblance to the national picture (Harrington 1982).

The Recent Trend in Fire Incidence

In a country of Canada's size and diversity, the annual national burned area is a complex statistic. Because of the immense range in value among burned hectares, it is better conceived as a sort of weather vane rather than as a direct measure of economic impact. Nevertheless, it is the best available single yardstick of forest fire activity in the country as a whole. Its trend over seven decades is shown in Figure 1, smoothed by an exponential process (Van Wagner 1988) in which the current year receives a weight of 0.1 and each successive year into the past correspondingly less. As of 1970, anyone could have looked back at a long downward trend and be forgiven for assuming that it might continue indefinitely. Instead, by the mid-1980s, the national average burned area had more than doubled and now stands higher than at any time in the recorded past. In the early years, records were no doubt less than complete; if so, this would serve only to accentuate the downward trend over the first four decades. (It is fair to assume a reasonably complete record at least within the past 20 years.) It is also true that much, but by no means all, of this upward trend is due to three particular years; 11 other recent years have also been distinctly above the exponential "mean" as it stood about 1970.

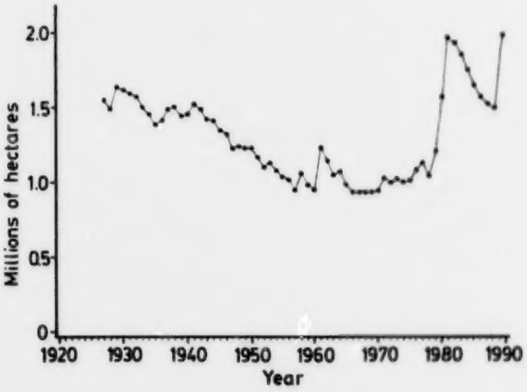

Figure 1. Trend of annual burned area in Canada from 1927 to 1989, smoothed by an exponential process giving 0.1 weight to the current year, from Van Wagner (1988).

No attempt is made here to interpret this trend in a climatic sense; that is a job for climatologists. However, it is common knowledge that a high national burned area is only possible in a year when the spring and summer weather over some large part of Canada is especially favourable to the spread of fire. In other words, in each extreme year, the burned area and the weather record match very well indeed.

The obvious future uncertainty implied by Figure 1 only serves to emphasize the importance of collecting all pertinent forest fire data, and then of interpreting the data rigorously in the most logical way.

Fire and the Timber Supply

The Static Analysis

The most recent attempt to measure and interpret the impact of fire on the forest inventory and available timber was made by Honer and Bickerstaff (1985). Their consolidated results (listed in their Tables A and B) provide an annual balance of accruals and depletions, separately for volume and area, for the entire Canadian productive forest for the period 1977-1981. An abbreviated version of this balance is presented here in Table 1. For the sake of discussion, assume that these data represent all that is known about a hypothetical forest.

At first glance, one quickly observes that fire and pests together depleted the same volume as was harvested, and also accounted for two thirds of all the area taken out of production. In fact, fire and pests together killed a volume equal to 42.5% of the forest's annual increment.

At second glance, however, one notes that the annual volume balance shows a positive 50.5 million m^3. Alone, the simple data in Table 1 do not tell whether the depletion by fire and pests hindered the industry in this forest in any way at all. It apparently took all the wood it desired, while another 35% was there for the taking. In the absence of an age-class distribution, one cannot tell whether the surplus volume represents a preponderance of high-volume overmature timber awaiting liquidation or a roughly balanced forest being underharvested for whatever reason.

At third glance, there is the annual area deficit of 0.45 million ha, which enters the category of not satisfactorily restocked. It is made up of contributions (in different proportions) from all depleting agents and is balanced, in part, by annual natural regeneration of old not satisfactorily restocked land (in this case, 0.12 million ha). Given an annual 0.45 million ha deficit, the current 21.9 million ha not satisfactorily restocked would be reached from scratch after about 50 years. Fire is an ancient process; therefore, the component of not satisfactorily restocked land contributed by fire should be in a state of rough equilibrium, rather than in a state of buildup due to modern intervention in a natural system. If so, a rough calculation can be made as follows.

The proportion of not satisfactorily restocked land annually returned to productive status is 0.12/21.9, or

Table 1. Condensed annual balance of timber volume and stocked forest area in Canada during 1977-1981, based on the more complete data in Tables A and B of Honer and Bickerstaff (1985)

Item	Volume (million m^3)		Area (million ha)	
Capital (1981)				
Volume		21536		
Land SPFL[a]				198.4
NSR[b]				21.9
Accrual (annual)				
Volume growth		338.0		
Area regenerated				
Current affected areas			1.65	
Old NSR land			0.12	
Total				1.77
Depletion (annual)				
Harvest	143.7		0.76	
Fire	80.0		0.96	
Pests	63.8		0.50	
Total		287.5		2.22
Net gain (loss)		50.5		(0.45)

[a] Stocked productive forestland.
[b] Not satisfactorily restocked.

0.56% (Table 1). However, Honer and Bickerstaff (1985) transfer 30% of the annual burned area to not satisfactorily restocked based on provincial estimates. At equilibrium with the present burned area, the current not satisfactorily restocked area due to fire alone would be 30/0.56 x 0.96, or 51.4 million ha, several times the current total estimate of 21.9 million ha. The probable truth is that fire is a better agent of renewal than it is given credit for; the 30% failure factor is undoubtedly too high.

The interpretation of the volume surplus and area deficit may or may not be completely clear, but the natural impression given by the accrual/deficit timber balance is that a cubic metre of wood killed by fire or pests is a cubic metre that could not be harvested - and that a hectare burned or killed by pests is a hectare that could not be harvested.

Some serious doubts will be shed on this simple impression in the next section.

The Dynamic Analysis

Although the timber and area balance described above was derived over a specific time period, it is, in theory, simply the difference that an auditor would find between the initial and final states. This is, in effect, a static concept, leading to the implicit assumption that all agents of depletion intervene in the forest's dynamics in the same way. Although it is well known that they do not, the static balance, nevertheless, makes it appear so. For example, picturing the forest as a stack of age classes with the youngest on the bottom, it is generally conceded that fire takes a vertical slice through the whole age-class distribution, whereas harvesting takes a horizontal slice across the top. In fact, dealing with fire alone, it is not easy to visualize just how fire and harvest interact, even in the simplest of forests.

The essence of the problem is the true nature of what is known as "depletion." The conventional concept of simply maintaining two one-dimensional accounts, one for area and one for volume, does not tell the whole story. What fire and harvest normally have in common is, barring regeneration failure, to cancel growing time by resetting age to zero. Primary depletion, therefore, must be expressed as the two-dimensional product of area times age, in effect weighting each hectare set back to age zero by its age. Thus, when 10 hectares are cut at age 100, the real depletion is 10 x 100, or 1000 ha/year. When a forest is burned at age 25, the loss per hectare is only 25 growing years, and it would take 40 such burned hectares to match the 10 cut at age 100.

Volume loss is, by this concept, a secondary expression of depletion because volume is already represented to a large extent by the time dimension. In other words, time and space constitute the rigid (i.e., nonelastic and incompressible) framework in which forests grow and are managed, whereas volume is a complex, sometimes artificial, function of time. (Nonlethal agents, such as some insects and diseases, may act mainly through an effect on the yield over age curve without affecting age-class distribution, which constitutes another kind of volume depletion.)

The static balance cannot easily accommodate this concept. Some dynamic analysis is required. To illustrate, imagine a forest managed for timber production but subject to fire, and reduced to its most basic functions:

- The forest grows on a specified yield curve of volume over age
- The stand of highest volume is always harvested
- Fire burns (and kills) at random without regard for age
- Regeneration is immediate after harvest or fire
- Access and the free movement of wood are unlimited
- Salvage is ignored

The combined effect of fire and harvest, each at any chosen level, can then be readily simulated in the computer; for example, in the manner of Van Wagner (1983). The model simply operates the forest from year to year, harvesting and burning in the chosen proportions, and reports volumes and ages at the time of cutting or burning. By repeated trials, the optimum sustainable yield (annual allowable cut (AAC)) can be found for any given level of fire. Some examples follow based on a yield curve like that of black spruce in western Quebec (after Boudoux 1978).

In Figure 2, the horizontal dotted line represents the ideal area cut annually to provide the AAC in the absence of fire. If all depleted hectares were equivalent, as the annual burned area increases, the area available for harvest should decrease correspondingly (the sloped dotted line). In actual fact, the simulation automatically weights each depleted hectare by its age and the optimum harvested area decreases along the lower solid curve instead, about halfway between the dotted lines. Although it appears that the annual total area depleted rises with increased burned area, the true primary depletion, namely the weighted product of area by growing years, remains more or less constant.

Another problem with the conventional approach now arises, i.e., the computation of depletion, especially volume depletion, does not answer the right question. The dynamic analysis disposes of this problem, in effect, by ignoring it; the primary question becomes instead, How much timber volume is available from the whole forest in the presence of fire?

The result, again for the same forest as represented in Figure 2, is shown in Figure 3. The upper curve represents the sustainable equilibrium annual volume available, i.e., the AAC, as it decreases with increasing

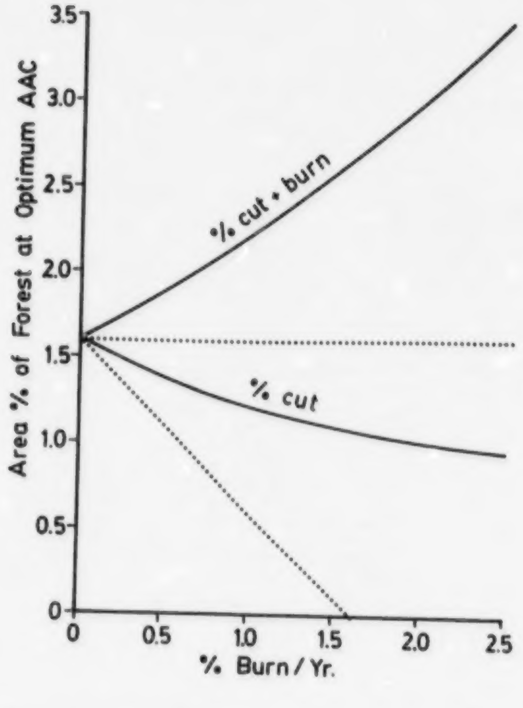

Figure 2. Curve of optimum annual cutover area versus annual burned area (lower solid curve), also the sum of these two (upper solid curve) for the simulated forest of Van Wagner (1983). See text for explanation of dotted lines.

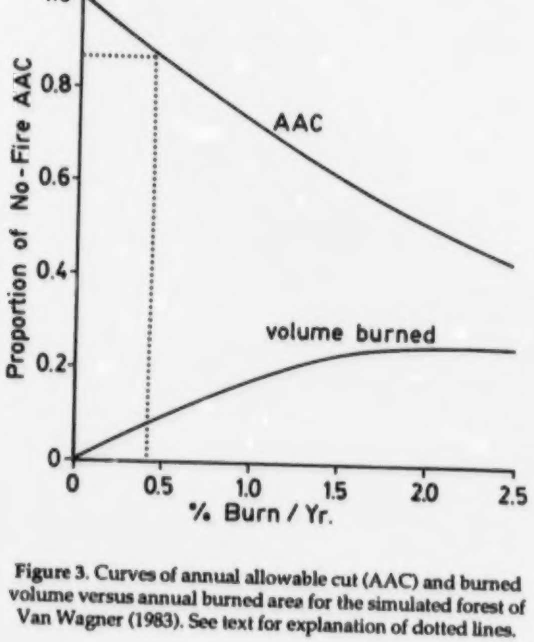

Figure 3. Curves of annual allowable cut (AAC) and burned volume versus annual burned area for the simulated forest of Van Wagner (1983). See text for explanation of dotted lines.

burned area. During the period covered by Table B in Honer and Bickerstaff (1985), Canada's productive forestland burned at the rate of 0.43% per year. At that level, as shown by the dotted lines in Figure 3, the available AAC would be 85% of the no-fire optimum, a reduction of 15% on account of fire. Based on the static balance presented in Table 1, fire killed a volume equal to 80/338, or 24% of the national annual increment. Not only is this percentage higher than the 15% reduction implied in Figure 3 but also it does not answer the right question. In fact, the volume killed by fire is a complex function of (1) the shape of the forest's yield curve, (2) its age-class distribution, and (3) the proportion of areas cut and burned. Thus, volume killed would, for a given level of fire, be greater in a forest overbalanced toward old age classes than in one fully regulated. Although in the equilibrium case (Figure 3) it is only 10% of the no-fire annual increment, the volume burned is, for purposes of dynamic analysis, a red herring.

In addition to Van Wagner's (1983) effort, there have been several recent Canadian interpretations of the impact of fire on timber supplies (Reed and Errico 1986; Newnham 1987; Dempster and Stevens 1987). Each has approached the problem differently - some mathematically, some by simulation - and at various levels of sophistication. All, however, agree on one fundamental point; they seek the impact of fire in the output from the whole forest, not on the burned area.

Implications for Forest Management

Several implications of dynamic analysis warrant discussion. The first is the matter of simulating to equilibrium. This process provides valuable information about forest potential in the long term, but the more immediate practical question everywhere in Canada is how to manage forests whose age-class distributions are far from ideal. In fact, any of the above models will, or can easily be made to, take any given initial forest state and show how yield will change over time during any planned transition to the optimum state permitted by the presence of fire.

Second, it is generally conceded that fire takes its toll across the entire age structure of the forest; this is the crucial difference between fire and harvesting. The present simulations (Figures 2 and 3) are based on the assumption that fire ignites and burns uniformly regardless of age. Although this may not be absolutely true, it makes a reasonable conservative assumption unless proven otherwise. In fact, the bulk of Canada's burned area is sustained in large fires burning at high or extreme fire danger; such fires may slow down or speed up to some extent from stand to stand, but the net result is more or less as assumed above and described by Van Wagner (1978).

Third, simulations based on constant annual burned area obviously do not account for the great real variation from year to year. This variation is clearly a scale phenomenon. Thus, within any part of a large region exposed to an average long-term probability of burning, the particular local variation will vary inversely with the size of the sample area. At one end of the scale is the nation itself, in which burned area (as mentioned earlier) has ranged within a ratio of 23:1 over the past 15 years, with a maximum equal to 3.3 times its mean. The other end of the practical scale might be the economic working circle around a large mill. Fire might leave it alone for years on end, then suddenly burn much of its area. Any analysis of the effect of annual variation must take this scale factor into account. In any case, it can readily be shown, by incorporating variable annual fire into the same simulation used so far, that the corresponding variation in annual timber supply is greatly damped in comparison with the variation in burned area that causes it. For example, based upon Van Wagner (1986), when the maximum burned area is 7.5 times the average (double the national case), the annual harvest under simple area control would fall in most years within ± 10% of the constant-fire optimum. A little volume control as well could smooth the pattern still further. One obvious reason for this damping effect is that each fire season affects the harvest in future years, and the effect of any extreme year, whether high or low, is greatly diffused by the time the next cuts are due. (A second reason becomes apparent below.)

Fourth, the nature of the damping principle discussed above suggests that the concept of strict age control be set aside because in any forest subject to variable fire, the current age-class distribution will also vary about a mean state, and timber volumes available from year to year at any given exact age will do likewise. Several authors (Martell 1980; Routledge 1980; Reed 1984) have shown mathematically that the optimum rotation at the stand level decreases gradually as random fire risk increases, and simple simulations like Van Wagner's (1983) automatically reproduce the same effect. At the whole-forest level, however, the concept of rotation takes, in effect, a back seat in the presence of variable fire. It becomes necessary, by common sense, to harvest as needed within a small range of ages about a mean. Provided the mean annual increment reaches a reasonably broad maximum over this age range, the yield will hardly be affected. The governing management principle, in turn, becomes area control rather than strict age control, with volume control as an additional sophistication to be called upon as desired.

Fifth, it is apparent from the curves in Figures 2 and 3 that the sensitivity of timber supply to fire decreases as the average annual burned area increases. Figure 4 demonstrates this still more graphically. For example, in the simulated forest a volume equal to, say, half the theoretical no-fire maximum is available in stands of similar age and volume almost without regard for the amount of fire. There is, in other words, no sharp cutoff or point at which it could be said that fire takes all the annual increment. As the annual burned area increased, the forest would probably fail ecologically first.

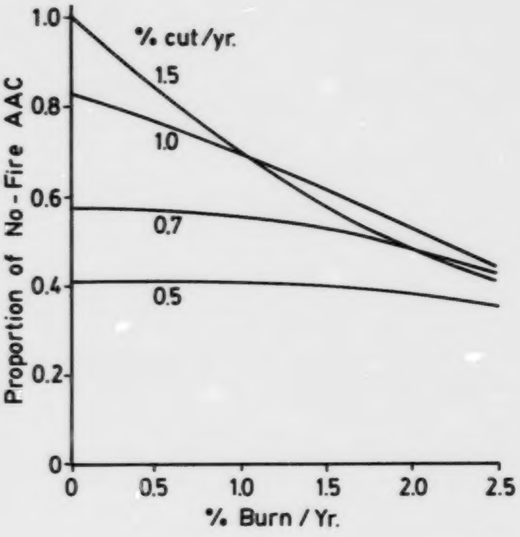

Figure 4. Curves of potential harvest volume for various annual harvest areas versus annual area burned for the simulated forest of Van Wagner (1983).

Sixth, what about economic implications? To begin with, timber supply analysis as discussed so far is obviously a large-scale affair. At the level of a large region or entire province, the timber supply clearly comes from the whole forest; furthermore, fire control in Canada is organized on the same large scale. If so, the economic measure of fire's impact is presumably the value of the reduction in timber supply below the no-fire optimum. The governing principle would be "maximized net return" (Van Wagner 1985), the balance point being, in simple terms, when the marginal cost of further reduction in burned area just equalled the value of the corresponding increase in available timber. But the traditional framework for fire economics has, for many decades, been "least-cost-plus-loss," with loss being defined as the "net value change" on the burned area (Althaus and Mills 1982). In the latter concept, the value of fire-killed timber (discounted in the case of young growth), far from being a red herring, becomes the primary measure; furthermore, as described by Althaus and Mills (1982), substitution is not allowed on theoretical grounds. It is not the intention to debate this issue here (other economic principles are no doubt involved), but only to suggest that any analysis of fire's economic impact cannot succeed unless it matches operational reality at the chosen scale and level of organization.

Conclusion

Given the nearly limitless capacity of modern computers and the advent of the geographic information system for organizing and presenting data, it is easy to describe the ideal forest fire information world. Once the Canadian forest is adequately inventoried to the stand level, every fire area would simply be digitized, and out would come the required mensurational details: age, species, volume, etc. Conceivably, remote sensing could be the ultimate source of all this information, at least of the burned areas and their locations. Of course, even before such a technological millennium, a great deal more could no doubt be done to document burned areas, permitting more confident tabulations of fire depletion than are now possible.

The main conclusion drawn here is that a static depletion balance will not give the correct answer to the questions, What is the impact of forest fire on the nation's timber supply? and What should be done about it? The answer will be found in the impact on the timber supply from the whole forest, not in the fire-killed timber on the burned area. The modern geographic information system can easily keep track of the burns and the holes they make in the forest inventory. However, it will take modern timber supply models with rational means of projecting the effects of future fire to design the optimum management regime for fire-prone forests.

The intention of this paper was not simply to show that the impact of fire on the nation's timber supply is probably less than is commonly believed. After all, a truly valid comparison of the static and dynamic approaches would require at least a complete yield over age curve for the hypothetical "national forest" and, if possible, an age-class distribution as well. Instead, the main point is that fire, and pests, are so important in Canadian forest management that only the most objective data and the most logical methods of analysis should be used to draw conclusions about their impact.

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National Data on Forest Pest Damage

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Abstract

Timber growth loss and mortality caused by the major forest insects and diseases in Canada are measured and reported by the Forest Insect and Disease Survey of Forestry Canada, in cooperation with provincial forestry agencies. The most recent national depletion estimates are presented, and the methods used to calculate these estimates are described. As quantification procedures are complex, depletion estimates begin with the organization of fundamental data before progressing towards the provision of regular statements on the effect of pests on timber supplies. To achieve this last goal, the current momentum in depletion estimation must continue by increasing the application of computer tools, sharing and integrating surveys and information between provincial and federal agencies, demonstrating the use of statistics in decision-making, and formulating clear policies for generating and reporting pest statistics.

Résumé

Le groupe du Relevé des insectes et des maladies des arbres de Forêts Canada, en collaboration avec ceux des organismes forestiers provinciaux, mesurent les pertes de croissance et la mortalité attribuables aux principaux insectes et maladies des arbres au Canada et publient un rapport annuel à cet effet. Les estimations les plus récentes de l'épuisement de la ressource à l'échelle nationale sont présentées et les méthodes utilisées pour les calculer sont décrites. Les méthodes de quantification étant complexes, les efforts déployés en vue de l'estimation de l'épuisement de la ressource ont débuté par l'organisation des données de base avant de pouvoir arriver à publier des relevés réguliers des effets des ravageurs sur les réserves de bois sur pied. Pour atteindre ce dernier objectif et continuer d'améliorer l'estimation de l'épuisement de la ressource, il faut multiplier les applications des outils informatiques, partager et intégrer les relevés et l'information des organismes provinciaux et fédéral, faire la preuve de l'utilité des statistiques dans le processus décisionnel et formuler des politiques claires en vue de la production et de la publication de statistiques sur les ravageurs.

Introduction

When changes to the forest are caused by humans or most abiotic phenomena, their impact is usually clearly evident: not always predictable, but often definable once the change has occurred. For example, wildfire and harvesting are well structured events that operate on diverse biological systems. A large part of the effort required to understand these events and quantify the results is normally due to the complex nature of the forest, not the activity. Consider the interaction of two biological systems: insects and diseases and the forest. The complexity increases exponentially to the point where, at times, the activity seems chaotic. We can now recognize the cumbersome task that forest pest scientists and managers are faced with in terms of understanding and describing forest/pest interaction.

Insects and diseases are ubiquitous in the forest habitat, and are often endemic, causing continual or sporadic, but minor, changes to standing timber through their activities. The growth loss and mortality that occur are often classed as "natural" processes; therefore, their quantification may be regarded as unnecessary. However, the question to ask is whether we should manage these processes to increase growth and yield?

Insect populations and disease intensities come to our attention when they cause rapid, drastic, and uncontrolled changes in forest habitats. This change is called damage. Where damage is obvious, the location of the outbreak can be detected and delineated. Although tree mortality during outbreaks is an important part of depletion, outbreaks also significantly reduce forest growth. The long-term losses associated with reduced growth may be greater than those associated with the tree mortality that occurred during an outbreak; this is seen, for example, with the forest tent caterpillar and jack pine budworm.

Forest loss data cannot be limited simply to a reduction of current timber volume. After all, this does not reflect future losses from current damage. For example, damage to plantations and young stands may be low in terms of current volume loss, but high in terms of future losses of high value timber. Except in severe outbreaks, expressing loss data as areas withdrawn from capital is not appropriate. Capital area losses are relevant to forest activities that are spatially complete at the stand level, such as fire, harvesting, and silviculture. Reference to areas of insect and disease damage is awkward because individual trees, rather than whole stands, are often depleted. For uniformity, the proportion of depleted volume to standing forest inventory volume can be related to the inventory area to derive a depleted area. These "area equivalent" figures have been developed for pest losses in the past (Honer and Bickerstaff 1985). A weakness of this approach is that it greatly underestimates the area affected. Even when only a fraction of a stand is lost, under this system the stand may fall into economic inoperability. Often, "area" is used to describe the size and location of a certain level of pest activity (e.g., moderate to severe defoliation). However, area pertains to the total forestland, including nonproductive land and minor water bodies.

At regional and national levels, it is important to relate losses caused by insects and diseases to other forms of losses and to the timber resource available. Such comparisons show the composition of the pest management problem. Analysis has revealed that (1) pests have a major influence on forests; (2) there is much to be gained in managing this damage; (3) damage does not always occur as a single catastrophic event; consequently, managers may not be aware that a crisis is developing; and (4) pest/forest interaction is complex; therefore, monitoring and managing this interaction is complex.

In this report, procedures, problems, and results related to quantifying forest pest damage in Canada are discussed and recommendations are made for further progress. The focal point is the Forest Insect and Disease Survey (FIDS) of Forestry Canada, which is primarily responsible for monitoring national pest depletion and providing essential data to the forest inventory. Provincial forestry agencies provide support to this federal effort in several different ways.

Definition of Terms

Damage can be biological, ecological, economical, or recreational. Each of these types of damage will yield different data. Until now, FIDS has concentrated on defining the current biological depletion (not to be confused with "loss") of standing timber volume resulting from pest activity and disease. This effort is regarded as an important first step at a national level, prior to estimating long-term effects and considering other factors to arrive at a net biological "loss." The last step is expressing impacts in a manner that is useful for management decision-making.

In this report, the average annual growth loss and tree mortality estimates for the period 1982-1987 (a 6 year period established by FIDS for national reporting of depletion statistics) is presented. Depletion is expressed as cubic metres of gross merchantable timber volume, except in British Columbia where volume is net.

The terms "endemic" and "epidemic" are considered inappropriate to separate so-called normal from abnormal forest insect situations. To distinguish between the two properly, one must select a management threshold below which control measures cannot be justified. Within the context of this report, the use of "population numbers" may be more appropriate (Knight and Heikkenen 1980).

Major Insects and Diseases

Of the thousands of insect species and diseases that occur in the Canadian forest, only a few cause major damage. The effects are regularly monitored by FIDS regional units. The following pest groups have been singled out for national damage reporting: spruce budworms, jack pine budworm, hemlock looper, mountain pine beetle, spruce bark beetle, other bark beetles, aspen defoliators, miscellaneous defoliators, dwarf mistletoe, hypoxylon canker, decays, root rots, and miscellaneous diseases. Each group is described later in more detail. All area and volume depletion figures are annual averages for the 1982-1987 reporting period.

Spruce Budworms

The two important spruce budworms in Canada are the spruce budworm *Choristoneura fumiferana* (Clem.) and the western spruce budworm *C. occidentalis* Free. The spruce budworm is the insect that causes the greatest damage to Canada's forests as a whole. It ranges from Newfoundland, throughout the boreal forest, to northeastern British Columbia, the Yukon, and the McKenzie River valley. It defoliates balsam fir and red, white, and black spruce, with larvae feeding on the base of needles, developing buds, and new shoots. Outbreaks have occurred every 30-100 years (Blais 1985) and consecutive years of defoliation result in reduced increment growth and, ultimately, tree mortality. Moderate to severe defoliation declined during the 1982-1987 period.

In Canada, the western spruce budworm is found in British Columbia, Douglas fir being its principal host. Defoliation by this insect results in growth loss, seed loss, top kill, and sometimes tree mortality. Two other spruce budworms were active in British Columbia, the 2 year cycle budworm *C. biennis* Free. and a 1 year cycle budworm *C. orae* Free., but these did not cause appreciable forest depletion (Kondo and Moody 1987).

Jack Pine Budworm

The jack pine budworm *Choristoneura pinus pinus* Freeman is common throughout the range of jack pine in Ontario and the Prairie provinces. Outbreaks last 2-3 years on a 6-8 year cycle (Ives and Wong 1988). Defoliation results in growth loss and top kill, but mortality is rare.

Hemlock Looper

The eastern hemlock looper *Lambdina fiscellaria fiscellaria* (Gn.) occurs throughout Canada, but has its greatest impact in Newfoundland. This insect feeds mainly on the needles of balsam fir. Outbreaks last 3-6 years, with 10-15 years between outbreaks (Kondo and Taylor 1986). Some growth loss occurs due to defoliation and trees can be killed in 1-2 years.

Mountain Pine Beetle

The mountain pine beetle *Dendroctonus ponderosae* Hopk. is the most destructive insect in western Canada. It is found throughout British Columbia and the mountain regions of Alberta, and in the Cypress Hills of Saskatchewan. Its primary hosts are lodgepole pine and

western white pine. The insect kills trees through girdling and transmitting blue stain fungi (*Ceratocystis* spp.).

Spruce Beetle

Although the spruce beetle *Dendroctonus rufipennis* (Kirby) occurs throughout Canada, it has been most damaging in British Columbia, Alberta, and the Atlantic provinces. White, Engelmann, and Sitka spruces are hosts of this beetle, and mortality results from feeding in the cambium tissue.

Other Bark Beetles

The eastern larch beetle *Dendroctonus simplex* LeC. attacks larch and is significant mainly in the Atlantic provinces. It has caused extensive tree mortality, but it is in the declining phase of its outbreak (Langor and Raske 1989). The Douglas fir beetle *D. pseudotsugae* Hopkins does much of its damage by attacking trees already stressed by the Douglas fir tussock moth *Orgyia pseudotsugata* (McD.) (Kondo and Taylor 1984).

Aspen Defoliators

A major defoliator of aspen is the forest tent caterpillar *Malacosoma disstria* Hbn., which often causes growth loss, but rarely brings about mortality. This insect also attacks a wide variety of hardwoods, such as oaks, maples, birches, and elms, decreasing the beauty of forests and ornamental trees. Across Canada, outbreaks last 4-5 years and occur every 6-16 years (Ives and Wong 1988).

The large aspen tortrix *Choristoneura conflictana* (Wlk.) is found across Canada and causes some growth loss during 2-3 year outbreaks (Ives and Wong 1988).

Miscellaneous Defoliators

The gypsy moth *Lymantria dispar* L. is an important pest of a wide variety of hardwoods in Ontario, and to a lesser degree in the Maritimes and Quebec. It is periodically introduced into British Columbia. Control actions are taken because of the potential effects on exports, recreational values, and aesthetics.

The Douglas fir tussock moth is an important pest in British Columbia, where tree mortality follows quickly after defoliation.

The western blackheaded budworm *Acleris gloverana* (Wlshm.) is a defoliator of old growth western hemlock, true firs, and spruce. One year of severe defoliation can lead to top kill and tree mortality (Kondo and Taylor 1986).

The spruce bud moth *Zeiraphera canadensis* Mut. & Free. occurs from Ontario through to Newfoundland, but is a particular problem in white spruce plantations in the Maritimes (Kondo and Taylor 1984). Defoliation, shoot distortion, and tree deformation result from infestations. Nova Scotia red pine plantations have sustained shoot damage from the European pine shoot moth *Rhyaconia buoliana* (D.& S.). In Ontario, white pine weevil *Pissodes strobi* (Peck) and pine bark adelgid *Pineus strobi* (Hartig) continue to plague white pine plantations (Kondo and Taylor 1984). The black army cutworm *Actebia fennica* (Tausch.) has defoliated thousands of white spruce and lodgepole pine seedlings in British Columbia and several black spruce plantations in Newfoundland.

Dwarf Mistletoe

Dwarf mistletoe *Arceuthobium* spp. cause serious diseases in lodgepole and jack pine, western hemlock, western larch, Douglas fir, and spruce in western Canada (Kondo and Taylor 1986). These parasitic plants distort branches and reduce growth by 30-60%.

Hypoxylon Canker

Hypoxylon canker *Hypoxylon mammatum* (Wahl.) J.H. Miller is an important disease of trembling aspen, occurring throughout its range from Alberta to the Maritimes.

Decays

Brown cubical rot *Coniophora puteana* Pers. and *Fomes pinicola* (Sw. ex Fr.) Cke., brown cubical butt rot *Polyporus sericeomollis* Rom., red butt rot *P. tomentosus* Fr., and white stringy rot *Poria subacida* (Pk.) Sacc. are a number of diseases that contribute to decay (Kondo and Taylor 1986). Decays set in after the trees have been stressed or wounded by other agents.

Root Rots

A number of diseases that cause stem decay are also responsible for root rot. *Armillaria* spp. cause significant diseases that bring about mortality in conifers and hardwoods. Both natural stands and plantations may be seriously affected.

Miscellaneous Diseases

Scleroderris canker *Gremmeniella abietina* (Lagerb.) Morelet occurs across Canada except in Saskatchewan, Manitoba, and Prince Edward Island (Kondo and Taylor 1984). This fungus has two races, North American and European, the latter causing serious problems in young pine plantations. In the Maritimes, the European larch canker *Lachnellula wilkommii* (Hartig) Dennis causes branch damage and mortality in young larch stands (Kondo and Moody 1987).

Dutch elm disease *Ceratocystis ulmi* (Duis.) C. Moreau is a fungus transmitted by elm bark beetles that causes extensive tree mortality. Damage to elms east of Saskatchewan has continued throughout the 1980s, but tree mortality has been greatly reduced through integrated pest management practices.

The sirococcus shoot blight *Sirococcus conigenus* (DC.) P. Cannon & Minter attacks a wide range of softwoods, but is a particular problem with red pine in the Maritimes where crown dieback and tree mortality occur (Kondo and Taylor 1986).

The decline of maple in Quebec, the dieback of birch and sudden death of balsam fir (Stilwell's Syndrome) in New Brunswick, and dieback of oak in Ontario are serious diseases, but their causes are not well understood (Kondo and Taylor 1986). Climate-related diseases include drought, frost, needle droop, and red belt. Other losses result from quarantine actions, such as the recent embargo on softwood chips by certain countries, related to the pinewood nematode.

National Summary

The 1982-1987 depletion estimation exercise has not yet been completed, but, for the purpose of this report, preliminary estimates are presented in Table 1. The spruce budworm is clearly the dominant forest pest, with moderate to severe activity (Figure 1), depleting the largest volume of timber (Figure 2). Growth loss due to the major forest pests is significant when compared with mortality caused by these pests during high population levels, indicating the importance of including growth loss when reporting pest depletion statistics.

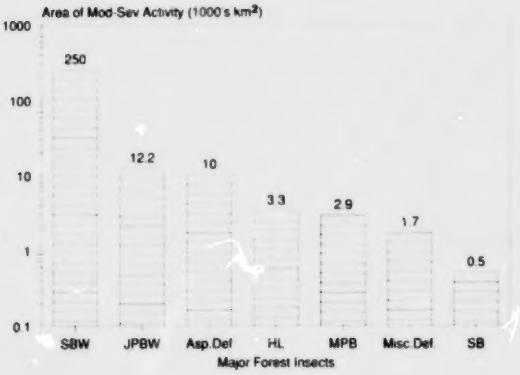

Figure 1. Major forest insects.

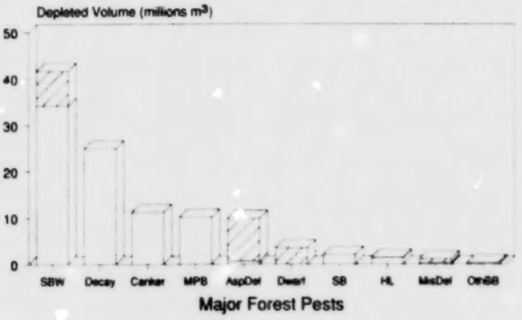

Figure 2. Major forest pests.

Survey Data on Forest Damage

The origin of the field data used to arrive at pest depletion estimates must be understood to interpret national data on forest pest damage. To quantify damage, an infestation must be measured, mapped, or sampled. Not all insect and disease damage manifestations lend themselves well to mapping. For many diseases, damage can be so widespread and homogeneously distributed that an entire region may be considered infested. Most of the damage that can be mapped is caused by defoliators, the most important group of pest insects.

For years, aerial sketch mapping has been the primary method used to delineate and classify defoliation and the extent of mortality. Field staff identify and classify defoliation and mortality in a general fashion using topographic maps at scales ranging from 1:100 000 to 1:250 000. Aerial sketch mapping has been successful despite certain difficulties that confront field staff, such as under- and overestimation, variation in judgement among observers, variation in observation and classification methods among regions, confusion between current damage and previous years' damage, and displacement in map registration (Sippell 1983; Power and D'Eon 1990).

On a national scale, aerial surveying in its current form and intensity is only suitable for damage estimates of large areas, except for some cases where the nature of the infestation and the effort spent on surveying yielded an accurate record of damage. This can be remedied only through an unlikely increase in survey resources, combined with operational remote sensing.

Each regional FIDS unit has a collection of infestation maps for the major defoliators. These maps can be loaded into a geographic information system (GIS) and used for damage assessment and prediction modelling. The chronology and impact of an outbreak can be analyzed with GIS tools. Overlaying a set of maps for a sequence of years will produce a composite of all activity over the period that can be related to the severity of impact (Power and D'Eon 1990).

Ground surveys and measurements help in delineating infestations that are not readily observable from the air. Also, these surveys provide impact information. At present, survey methods are standardized regionally, but not always nationally. They range from ad hoc observations to regular measurements of permanent impact plots. Impact plot measurements provide a history of pest activity and contribute to quantifying pest damage. Growth, yield, and depletion effects can be determined from these repeated measure-

Table 1. **Preliminary pest-caused timber depletion estimates for regions in Canada, annual averages for 1982-1987**

	Newfoundland				Maritimes				Québec				Ontario			
	Area	Growth Loss	Mortal.	Total	Area	Growth Loss	Mortal.	Total	Area	Growth Loss	Mortal.	Total	Area	Growth Loss	Mortal.	Total
Spruce budworms	900	126	1 158	1 284	76 920	602	6 227	6 829	78 820	5 000	16 800	21 800	90 130	1 200	9 720	10 920
Jack pine budworm	—	—	—	—	—	—	—	—	—	—	—	—	11 878	NA	NS	NA
Hemlock looper	3 200	47	1 391	1 438	—	—	—	—	—	—	—	—	—	—	—	—
Mountain pine beetle	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Spruce beetle	—	—	—	—	NA	—	295	295	—	—	—	—	NA		295	295
Other bark beetles	900	—	7	7	NA	—	181	181	—	—	—	—	NA	NA	NA	NA
Aspen defoliators	—	—	—	—	NA	845	—	845	2 570	500	—	500	4 251	1 342	650	1 992
Misc. defoliators	—	—	—	—	NS	NS	NS	NS	—	—	—	—	923	NA	NA	NA
Dwarf mistletoe	—	—	—	—	NA	NA	292	292	—	—	—	—	NA	NA	NA	NA
Hypoxylon canker	—	—	—	—					C	—	1 260	1 260	C	NA	6 180	NA
Decays					C	NA	799	799	C	—	2 584	2 584	C	1 089	10 770	11 859
Root rots	C	NA	NA	NA	C	NA	NA	NA	C	4 610	—	4 610				
Misc. diseases	—	—	—	—	C	—	84	84	—	—	—	—	NA	NA	4 180	NA

	Prairies and N.W.T.				British Columbia and Yukon				CANADA			
	Area	Growth Loss	Mortal.	Total	Area	Growth Loss	Mortal.	Total	Area	Growth Loss	Mortal.	Total
Spruce budworms	50	138	—	138	3 850	438	252	690	2 500 000+	7 504	34 157	41 661
Jack pine budworm	345	NA	NS	NA	—	—	—	—	12 223	NA	NS	NA
Hemlock looper	—	—	—	—	143	NS	NS	NS	3 343	47	1 391	1 438
Mountain pine beetle	111	—	385	385	2 813	—	9 776	9 776	2 900+	—	10 161	10 161
Spruce beetle	NA	—	48	48	378	—	1 708	1 708	450+	—	2 051	2 051
Other bark beetles	NA	NA	NA	NA	455	—	28	28	NA	—	300	300
Aspen defoliators	1 256	6 492	—	6 492	420	25	—	25	10 000	9 204	650	9 854
Misc. defoliators	NA	128	—	128	480	39	353	392	1 700	800	300	1100
Dwarf mistletoe	NA	NA	NA	NA	NA	2 748	—	2 748	NA	3 500	—	3 500
Hypoxylon canker	C	NA	2 970	NA	NS	NS	NS	NS	C	—	11 200	11 200
Decays	C	NA	NA	NA	C	13 018	—	13 018	C	NA	25 000	NA
Root rots	C	NA	NA	NA	C	2 000	1 400	3 400	C	NA	NA	NA
Misc. diseases	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: Area is given in square kilometres within which moderate to severe pest activity occurred. Depletion is given in 1000 m^3 of gross merchantable volume (except in British Columbia where volume is net). Abbreviations: NA, not available; NS, not significant; C, common.
Source: Forest Insect and Disease Survey regional units. Some gaps were filled by using rates from adjacent regions, as well as figures from the 1977-1981 depletion exercise.

ments. Although not all combinations of pest history, stand composition, stand age, and host stand type can be represented, these plots do provide a broad mosaic of the whole pest situation throughout Canada. Extrapolation fills the gaps.

A major portion of ground surveys are recorded in a national data base, FIDSINFOBASE, for regional access. These data are extensive, complex, and detailed and do not lend themselves to impact interpretation other than by regional FIDS staff. Other records, most of which are not yet in a digital format, are maintained by regional FIDS units. These are data from specialized surveys of pests, such as egg surveys to forecast regional outbreak populations; on insect and disease conditions in nurseries, plantations, young stands; and on stand impact.

Scientific judgement must be used with conventional survey data to develop a rational picture of damage. Because all of the information cannot be captured and recorded, field experience related to and scientific knowledge of insect and disease activities form a valuable component. Much of the knowledge is isolated within experts, and is normally only communicated as a decision or recommendation. Extracting and recording the facts and rules that make up the knowledge may be the best opportunity for expanding data bases for forest pest damage assessment.

Relating Damage Estimates to Forest Inventory

The extent of forest damage must be expressed in relation to the entire forest inventory. Regional estimates of pest-caused depletion developed by FIDS units are reported in relation to either the provincial inventory or the national forest inventory depending on the agreement with the province. The national forest inventory, the Canadian Forest Resource Data System (CFRDS), is a compilation of all provincial forest inventories (Forestry Canada 1988). There are a number of advantages and disadvantages related to using the national forest inventory for reporting pest damage (Power and D'Eon 1990).

1. The national forest inventory provides a common bench mark to compare all changes in forest activities.
2. The national inventory is compiled from provincial data at a given time and provincial data are modified to adhere to a common standard. Consequently, expressing damage in relation to provincial data will result in a different numerical value than would be derived if damage was expressed in relation to the national inventory.
3. Ideally, a forest inventory should represent the state of the forest on the starting date of a damage estimation or modelling procedure. This feature is not available in the national forest inventory nor in most provincial inventories.
4. Separation of host tree species in the national inventory is not always possible because some species are grouped by genus. For example, information on the oak species or genus cannot be extracted as it is grouped under "other broad-leaved species." The national inventory is difficult to use to estimate depletion caused by the gypsy moth, for instance, because depletion can vary dramatically between oak species and between tree genera.
5. Growth and yield data, at present, are not available in the national inventory, although hardwood and softwood growth rates are reported for each forest section in Canada (Rowe 1977; Bickerstaff et al. 1981). These rates are used only as a last measure.

To prepare forest inventories for depletion estimation, area and volume data on the tree species that are hosts to the pest of interest must be extracted. Figure 3 is an example of a tree host inventory developed for the spruce budworm in Canada using species volumes and stand composition data from the national forest inventory.

Relating host inventories to both pest mapping and impact surveys requires matching inventory location and attributes. Depending on the purpose and required accuracy, these matches can be done by individual stands or by map sheet summaries. Geographic information systems play an important role in automating this process when digital maps of infestations and the forest inventory are available. Major portions of Canada's forests have been loaded into GISs by stands, but as yet these are incomplete for nationwide damage reporting. Fortunately, a digital map of the national forest inventory (CFRDS) grid, where each grid cell represents a provincial inventory map sheet, is available for overlaying tree host inventories with pest infestation maps.

National Pest Depletion Estimation Exercise

The first national exercise for developing statistics on forest depletion caused by insects and diseases covered the period 1967-1976 (Anon. 1979). Results of the second exercise, covering the period 1977-1981, are shown in Table 2.

The intention of the current (third) exercise was to prepare growth loss and mortality estimates for the period 1982-1987. Growth loss was dependent only on pest activity during the period. However, tree mortality was dependent on the cumulative pest activity during the reporting period and on pest activity previous to that.

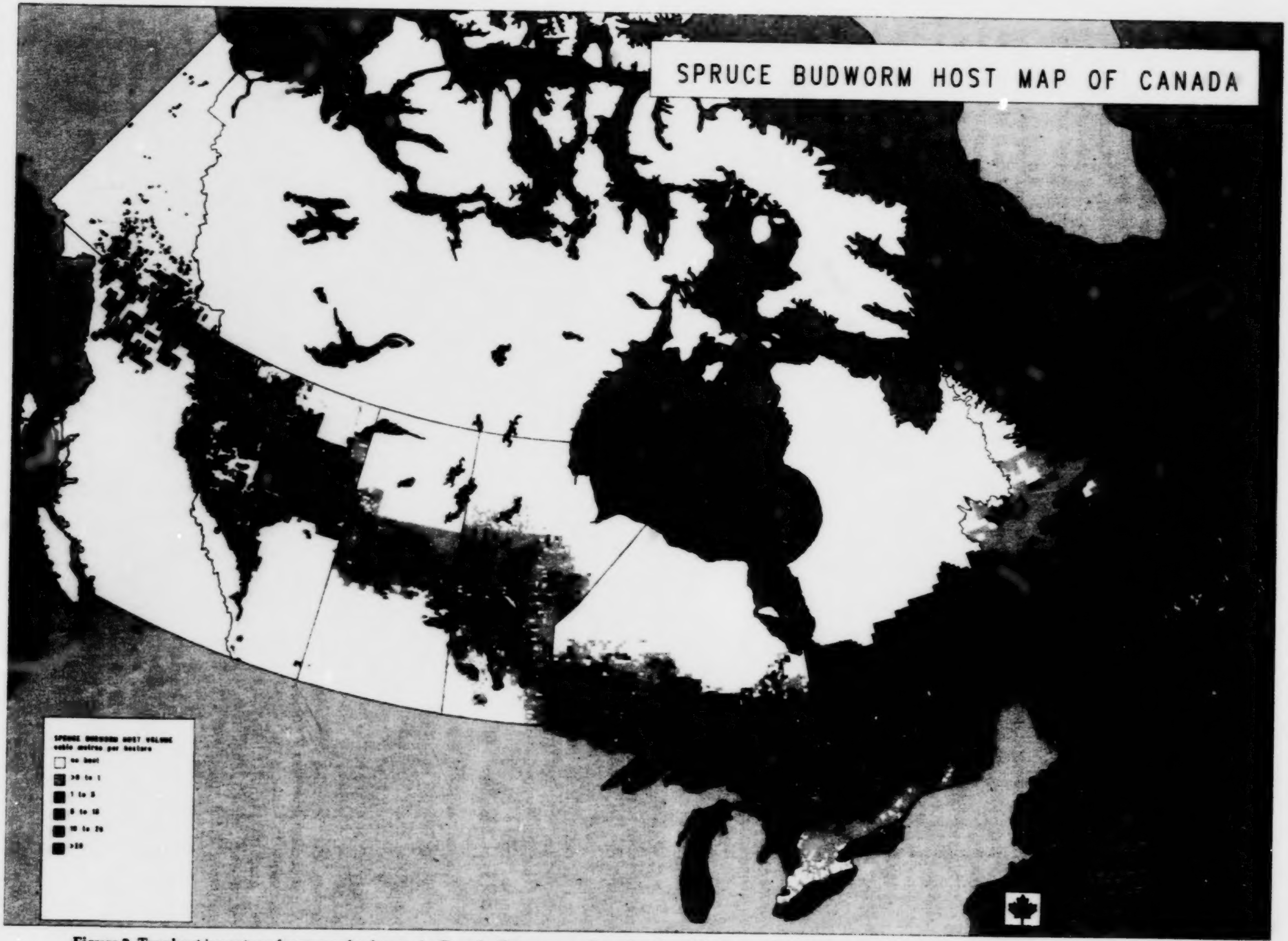
SPRUCE BUDWORM HOST MAP OF CANADA
SPRUCE BUDWORM HOST VOLUME
cubic metres per hectare
no host
>0 to 1
1 to 5
5 to 10
10 to 25
>25

Figure 3. Tree host inventory for spruce budworm in Canada. Data source: Canadian Forest Resource Data System. Produced by: Pest Management Systems - PNFI - 1990. Authors: Tom Gillis and Stephen D'Eon.

Table 2. Estimated average annual depletion (million m^3) for 1977-1981 caused by important forest pests in Canada

	Mortality	Growth Reduction	Total
Insects			
Spruce budworms	34.8	9.7	44.5
Mountain pine beetle	5.1		5.1
Spruce bark beetle	3.5		3.5
Other bark beetles	0.3		0.3
Aspen defoliators		8.0	8.0
Misc. defoliators	0.3	0.8	1.1
Total insects	44.0	18.5	62.5
Diseases			
Dwarf mistletoes		3.8	3.8
Hypoxylon canker	11.2		11.2
Decays		25.0[a]	25.0
Misc. diseases		4.9	4.9
Total diseases	11.2	33.7	44.9
Total Pests	**55.2**	**52.2**	**107.4**

[a] Wood destruction only.

Source: Sterner and Davidson (1982).

Computer procedures for GISs and data base management systems were developed to assist in estimating depletion when much data processing was required (Power and D'Eon 1990). These procedures were used for pests whose areas of intensive activity were detected and mapped (primarily the defoliators) and for pests that are homogeneously distributed across forest regions (root rots). This depletion estimation system is given as an example to illustrate the scope of such an exercise.

All infestation maps for 1982-1987, plus a certain number of maps from previous years (up to 10 years for spruce budworm), were needed to derive the infestation history for any part of the forest. Infestations on these maps were classified by activity, i.e., light, moderate, or severe. After loading these maps into a GIS, composites of infestation histories were determined rapidly; manually, this task is very inaccurate and time consuming. Each infestation history is a unique sequence of events (e.g., year 1, light defoliation; years 2 and 3, moderate defoliation; year 4, light defoliation, etc.) pertaining to a specific forest location. Each location is a unique polygon, the product of overlaying and intersecting all annual infestation maps. The number of composite polygons produced can be very high and depends on the pattern and complexity of the infestation. For example, overlaying defoliation maps for spruce budworm in New Brunswick for 6 years yielded over 20 000 polygons.

The proportion of host volume depleted within each composite polygon was calculated from growth loss and mortality rates. These rates were not readily available for all possible infestation histories occurring in all forest regions of the country; however, interpolation and extrapolation filled many gaps around rates that were available from field measurements. For other gaps, data were exchanged between regions and, where necessary, a consensus was reached as to the appropriate rates that may apply to each pest situation. For example, six regional studies indicated varying expected radial growth reduction rates for aspen given scenarios of forest tent caterpillar defoliation for 1-8 years (Amirault 1990). It was decided to combine the results to produce a more robust set of growth loss rates for all to use. These rates have now been adopted as a national standard.

The preliminary results of the national depletion exercise, as presented earlier in this paper, are an indicator of the magnitude of the forest pest problem in terms of timber depletion. Throughout the exercise, deficiencies in our knowledge of the impact of various pests have been exposed, thereby identifying areas for further research.

National Data Responsive to National Needs

The achievement of objectives for a national data base on forest pest damage is a process that starts with currently available data. As demands for pest information increase, these data bases can be expanded through new technology, knowledge, and experience. The current depletion estimation exercise sets the groundwork for moving FIDS, along with its provincial counterparts, toward producing better national pest information.

One of the most important benefits of this exercise is the acquisition and organization of basic forest data: infestation maps, a forest inventory, and depletion rates. A data acquisition and processing strategy to build on these data will enable us to continue the momentum of the present work. National needs for forest data and statistics have to be better articulated. We all believe in the need for forest statistics, but we don't always know why or how they will be used to make a specific decision. Despite this situation, a plan is suggested:

1. As depletion estimation is becoming more automated, less effort needs to be expended in future exercises to produce the same result. A regular schedule of generating statistics should eventually approach an annual cycle. In the system, only those data components that have changed need to be updated, such as the annual infestation maps. Depletion rates can be updated as research results become available. Forest inventory data can be updated according to provincial and national inventory schedules.
2. Depletion data should be incorporated into provincial inventory data bases to access stand data, and feed back the timber depletion for inventory updating. In this scenario, a national forest inventory would not be accessed; however, losses caused by pests could be incorporated into a national data base in synchrony with the 5 year provincial inventory roll up.
3. The calculation of depletion should be extended beyond the reporting period to show the long-term effects of growth loss and mortality on the future yield of the forest. This could be accomplished by inputting depletion data into timber supply and growth and yield models.
4. Depletion data should be adjusted to show the estimated loss of timber. For example, some activities may result in thinning the stand, improving its density, and increasing the yield of commercially desirable tree species.
5. Volume losses should be expressed in economic terms according to some national standard that enables placing regional or national timber values. Within this context, salvage of killed timber can be shown as a temporary economic gain, reducing the net loss.

Recommendations

Two key areas that will lead to improved national data on forest damage are "integration" and "automation." Sharing survey operations, data, knowledge, and systems will mean greater efficiency. Formalizing processes through automated systems not only decreases manual calculations but also helps standardization.

Pest surveys from the air and ground are expensive. Vast areas must be covered each year in a short period of time. However, no acceptable and operationally feasible method is available to replace aerial sketch mapping. Much hope remains for remote sensing to supplement aerial sketch mapping, but this technique has been slow in developing. Perhaps the time is right to evaluate the status of remote sensing technology so that, if the outlook is favourable, an implementation plan can be devised for pest surveys. When remote sensing becomes operationally feasible, it need not be used specifically for pest surveys, but could be shared by other surveys that detect and map changes to the forest for multiple resource management. Combining all applications that require a high resolution scan of the entire commercial forest every year would make remote sensing more economically acceptable from a pest survey context.

Establishing additional sample plots to monitor forest health and to measure the impact of pests will not likely occur while budgets remain tight. Opportunities should be sought to take advantage of other forest surveys involving plot measurements, in particular growth and yield, and to influence these surveys to include measurements of pest-related impact data. All air and ground surveying should be planned according to a multistage sampling scheme to obtain the greatest amount of information for the survey effort expended.

Standardization of data and methods is usually looked upon favourably by all parties concerned, but is difficult to accomplish. The recent national pest depletion estimation effort provided a forum for exchanging growth loss and mortality rates and for formulating the terms and format under which depletion can be meaningfully expressed. This must become a continual process.

Federal-provincial cooperation is already significant in forest insect and disease surveys and in sharing information. This cooperation must continue if the production of pest damage information is to be improved and expanded. With further agreements between Forestry Canada and the provinces, procedures, methods, technology, survey results, and analyses can be exchanged. The provinces can supplement FIDS information with further surveying and analysis to evaluate pest damage to their current and future timber supplies.

Statistics collected in pest surveys have to be defensible. Concerns related to accuracy and applicability must be addressed because these data can have political and economic repercussions. Background information, assumptions, and limitations of use must be clarified when statistics are presented. The data sets and methodology employed in calculations should also be included. Such a package of information will contribute to the acceptance of statistics by those with vested interests. Increasingly, the ability to attach information with statistics is being improved through the adoption of systematic approaches in depletion estimation.

Documentation is also important for guiding future exercises. Procedures can be recorded in internal or published reports, but are also inherent within well-constructed computerized systems. System development and implementation, building on current depletion estimation systems, should make better tools. These systems can incorporate the knowledge of scientists, managers, and field staff using artificial intelligence technology.

There is little incentive for FIDS and its provincial counterparts to generate detailed and regular statistics on pest damage unless there is an obvious benefit for planning and decision-making. The application of pest damage statistics must be demonstrated in areas such as forest sector analysis, so that within our policies, we can clarify the type, format, timing, and use of these statistics. Participation of the cooperators can then be secured.

Conclusion

Forest pest depletion figures alone cannot accurately describe the impact of pests on Canada's timber resources. Impact is a complicated process and has far reaching implications for forest practices. The complex process of deriving impact must relate damage data and knowledge to effects on timber supplies and on other increasingly important forest values, such as wildlife, water, scenics, and recreation. The Forest Insect and Disease Survey has set the groundwork of estimating pest damage, and must continue beyond depletion estimation to determine timber supply impact. This activity must be accomplished in cooperation with provincial forestry agencies. Information technology will play an important role in realizing this task. Before heading off in all directions, however, federal and provincial policies that dictate the need for pest damage information, including statistics, must be reviewed. With clear policies, our objectives will be better understood, accepted, and accomplished.

Acknowledgments

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Forestland Withdrawals in British Columbia - A Case Study

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Abstract

Prior to harvest forecasting, forest managers must define numerous assumptions and determine an operable land base for various timber harvesting scenarios in British Columbia's timber supply areas (TSAs). The Midcoast TSA, one of 35 TSAs within the province, is centred around the community of Bella Coola on British Columbia's west-central coast. The Midcoast TSA has recently undergone a timber supply analysis that investigated a range of land use assumptions. This paper presents the results of these land base assumptions, with respect to operable land base determination, and investigates additional land base scenarios based on potential extrapolations to address future land use demands.

Résumé

Avant d'effectuer des prévisions de la récolte, les aménagistes doivent émettre de nombreuses hypothèses et déterminer une superficie à exploiter selon divers scénarios de récolte dans les régions d'approvisionnement en bois de la Colombie-Britannique. La région d'approvisionnement en bois se situant au centre de la côte est une des 35 régions de la province et s'étend autour de la collectivité de Bella Coola, dans le centre-ouest de la côte de la Colombie-Britannique. Les réserves sur pied de cette région d'approvisionnement en bois ont récemment fait l'objet d'une analyse qui a examiné une série d'hypothèses des terres. Le présent article expose les résultats de ces hypothèses en ce qui concerne la détermination des superficies exploitables et il se penche sur d'autres scénarios relatifs au terres, fondés sur des extrapolations potentielles afin d'aborder les demandes futures d'utilisation des terres.

Introduction

The Midcoast TSA encompasses a total area of 2 340 000 ha of provincial Crown land. Of this total area, approximately 3% is currently earmarked for ecological, Indian, or special reserves.

The remaining land base of 2.270 million ha is distributed between the following four categories (Figure 1):

- nonforest: 1.53 million ha (67%)
- mature forest (stands greater than 120 years old, except pine and deciduous species that mature at 81 years): 676 000 ha (30%)
- immature forest (stands less than 121 years old, except pine and deciduous species that are immature until 81 years): 65 000 ha (3%)
- currently nonstocked: 4 000 ha

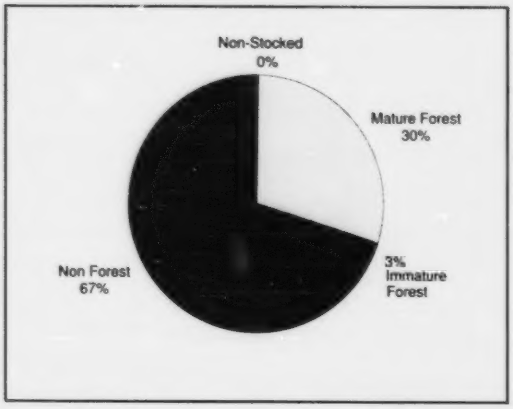

Figure 1. Midcoast TSA gross land base

The TSAs within the province comprise approximately 43 million ha of productive Crown forest. This figure represents about 52% of the total TSA land area. If only the coastal TSAs are examined, the productive Crown forest proportion drops to 41%. The Midcoast TSA has a total of only 33% of its gross land base classified as productive Crown forest.

Operable Land Base Determination - 1981

Timber supply analyses for provincial TSAs are conducted on a cyclical basis. Through the Ministry of Forests' planning process, an official operable land base is identified upon which the annual allowable cut (AAC) for a TSA will be set for the next 5 year period. The current AAC for the Midcoast TSA is 1 515 600 m^3/year.

Through analysis procedures, the 745 000 ha of productive Crown forest in the Midcoast TSA is further reduced, or netted down, through a process of land categorization. By applying different land use assumptions, an operable land base that is available for timber harvesting is determined for various scenarios. A number of these scenarios are presented here.

The previous analysis of the Midcoast TSA was completed in 1981. At that time, land use assumptions, which determined the operable land base, included reductions for forest stands classified as

- low site quality
- deciduous
- mature stands less than 19.4 m tall

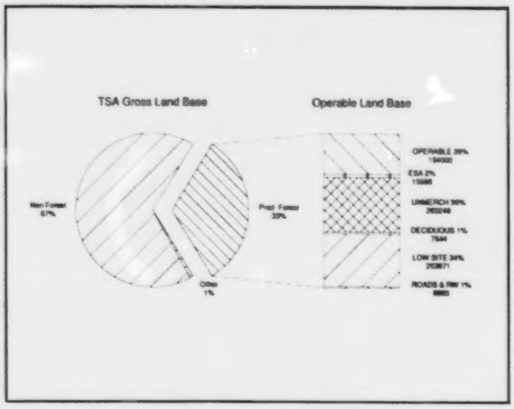

Figure 2. Midcoast TSA status quo land base definition.

- mature stands comprising less than 76 trees/ha greater than 27.5 cm dbh
- lodgepole pine types located in specific areas of the TSA
- other problem forest types dispersed throughout the TSA

The operable land base for timber harvesting, based on these 1981 assumptions, was determined to be approximately 246 000 ha, or only 10% of the total TSA (Figure 2). The Midcoast TSA's 10% operable land base figure is well below the provincial TSA average of about 24% of the total land base. Again, if only coastal TSAs are considered, the operable land base identified for timber harvesting averages about 20% of the total TSA land base.

Operable Land Base Determination - 1990

In early 1990, a new timber supply analysis was completed for the Midcoast TSA. Over the years, there has been a general movement away from broad, single "class" categorizations, as was the case throughout the analyses being conducted in 1981. The assumptions that are now used to determine the operable land base for timber harvesting have become more site specific in nature.

Today, assumptions range, for example, from "a 100% reduction for all areas classified as low site that are also less than 121 years old" to the complexity of "an inclusion of 12% of all lodgepole pine stands greater than 120 years old, with a site index of 12.0 or above, and a Crown closure percentage of over 40%, that are located in a specific watershed." The latter assumption definition represents what has now become known as area inclusion factors. The 1990 land base analysis for the Midcoast TSA was accomplished primarily in this manner.

These specific criteria are used to reflect a broad range of management assumptions within a TSA. Forest stands are reserved from harvesting for a variety of management reasons. These may include

- lands classified as being environmentally sensitive
- lands currently not economical to harvest
- lands that possess values for other resource use, such as recreation or wildlife habitat

In the latest analysis, the first scenario that was investigated determined, in a computer modelling sense, the operable land base upon which the current forest management in the TSA is practiced. This scenario is commonly called the status quo.

Based on the status quo assumptions, the current operable land base available for timber harvesting in the Midcoast TSA is 194 000 ha, or about 8% of the total TSA land base. This is about 50 000 ha less than was determined to be available in 1981.

Three scenarios, dealing specifically with land base withdrawals, were investigated in the Midcoast TSA timber supply analysis. These scenarios identify additional areas within the status quo operable land base that will reflect alternative management strategies. These areas included

1. The Dean River and Inside Passage Corridor study area
2. Areas included in two tree farm licence (TFL) proposals
3. Additional protection of the fisheries resource

All of these scenarios build upon the base assumptions that were defined for the status quo scenario. The effect, therefore, is a further reduction in the operable land base for timber harvesting.

The Dean River/Inside Passage scenario's net land base was determined to be approximately 187 000 ha. This is 7 000 ha less than the status quo scenario, or a further operable land base reduction of 3.6%. The TFL scenario's net land base was approximately 185 000 ha, a 9 000 ha (4.6%) reduction from the status quo scenario. Additional protection of the fisheries resource reduced the net land base to 182 000 ha or 12 000 ha less (6.2% reduction) than the status quo (Figure 3).

If it is assumed that these three scenarios are mutually exclusive, and all three management initiatives are pursued, the cumulative reduction to the status quo scenario net land base would be 28 000 ha (14.4%). The operable land base would be 166 000 ha. This is approximately 80 000 ha less than what was defined as an operable land base in the 1981 analysis, or a potential reduction of 33% in less than 10 years. The status quo scenario land base, which reflects current management

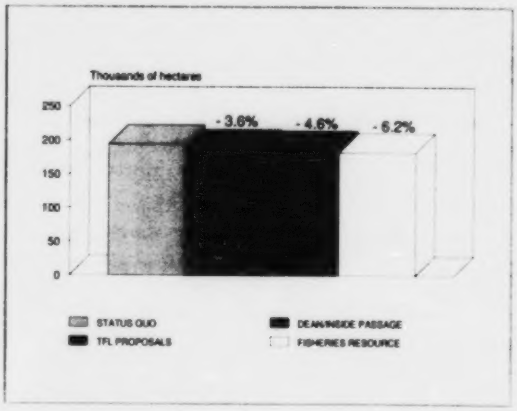

Figure 3. Midcoast TSA 1990 land base analysis results.

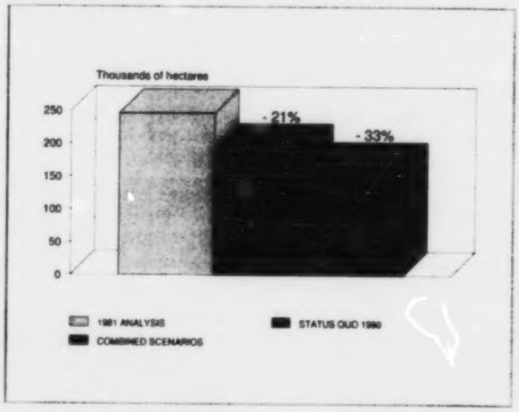

Figure 4. Midcoast TSA 1990 land base analysis combined scenario results.

practices, is 21% less than what was determined in 1981 (Figure 4).

These scenarios, amongst others, will form some of the alternatives that will be examined further over the next few months in the development of an Options Report, which is the next phase of the TSA planning process. The Options Report will not only look at the analysis of the timber resource but will also consider all other resource values within the TSA. Options will be evaluated, with a preferred option eventually being chosen. A revised TSA plan will then be developed for the TSA.

The revised TSA plan for the Midcoast TSA will set the operable land base and AAC for the next 5 year period. It is probably safe to assume that the land base supporting the AAC will not be as great as was defined in 1981. Will the AAC drop to reflect a reduced land base? That is a question that will be answered by the planners and the Chief Forester.

Future Land Withdrawal Pressures

Land use pressures in British Columbia will continue to increase and these pressures will have the largest effect on determining the operable land base for timber harvesting. The growing demand for nonconsumptive uses, such as wilderness areas, Native land claims, parks, and tourism, coupled with increasing environmental concerns about ozone levels, pollution, remaining old growth, biodiversity, and forestry practices will, over time, further reduce the land base that is available for timber harvesting.

In less than 10 years, as seen in the Midcoast TSA, an operable land base could be substantially diminished through land base withdrawals. These lower levels may not sustain current harvesting rates for another decade.

Depending upon the magnitude and momentum of land use pressures, we may eventually see entire TSAs, as they are now defined, devoid of any commercial harvesting activity whatsoever.

The next analysis, in the mid- to late 1990s, will probably see the 1990 net land base be reduced even further. This will occur not only in the Midcoast TSA but also in TSAs and TFL areas throughout the province.

The future will see land base analysis conducted on a stand-specific basis within the framework of geographic information systems and high resolution computer models. For this to happen, however, inventories must be improved, not only for timber but also for all other resources. History has shown what a tremendously large and difficult undertaking it is to establish and maintain accurate, current, site-specific timber resource inventories. Let us be thankful that trees do not possess legs or wings.

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5. Forecast to 2050

Canada's Timber Situation in 2050

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Abstract

The objective of this paper is to forecast the general magnitude of timber availability to the year 2050. The approach taken is first to lay the groundwork with a set of assumptions that seem likely to prevail. Then a rough comparison of existing harvest levels and annual allowable cuts will show that all the provinces except Alberta are experiencing deficits of softwood sawlogs, and in some cases even pulpwood supplies must be brought from long distances.

It seems reasonable to conclude, however, that new and visionary policies hold the promise of mitigating the worst of the anticipated falldowns in supply. At the same time, a doubling of the softwood harvest by 2050 and a much greater percentage expansion in hardwood species is possible. In addition to these volume gains, a marked increase in the value of timber from well-managed forests can be expected. The key is an aggressive program of intensive forestry, with interesting implications for funding and for sustainable development.

Résumé

Le présent article a pour objectif de prévoir l'ampleur générale des réserves de bois disponibles d'ici l'an 2050. L'approche utilisée consiste à établir d'abord une série d'hypothèses vraisemblables. Une comparaison sommaire des niveaux actuels de récolte et des possibilités réalisables annuelles montrent ensuite que toutes les provinces, sauf l'Alberta, connaissent un déficit des sciages de résineux et qu'elles doivent même, dans certains cas, aller chercher très loin leur bois de pâte.

Il semble toutefois raisonnable de conclure que des politiques nouvelles et éclairées pourront permettre d'atténuer les pires effets de l'effondrement prévu de l'approvisionnement. Simultanément, on peut prévoir le doublement de la récolte de bois de résineux d'ici 2050 et un pourcentage d'augmentation beaucoup plus important du volume d'essences feuillues. Outre cette progression, nous pouvons nous attendre à une augmentation marquée de la valeur du bois provenant de forêts bien aménagées. La clé du succès est un programme énergique de foresterie intensive avec les possibilités intéressantes de financement et de développement durable qu'il comporte.

Introduction

The objective of this paper is to look ahead to the supply and demand balances that are most likely to occur around the year 2050, and then to suggest ways in which Canada's forest destiny can be more readily achieved. The approach will be to set the stage and provide a realistic context for more detailed discussions in later papers.

Perhaps a comment on the length of the forecast is in order. It is rare, indeed, that attempts are made to look ahead 60 years. Foresters and forest sector analysts should not be frightened, as they often are, by the need to develop long-term strategies. This is a paradox that calls for serious reflection.

Postwar Trends

A brief sketch of forest sector trends since 1950 will provide perspective as we anticipate the directions of future development. Those who wish to trace our progress from an earlier point in time can do so readily. Reasonably good data go back to the turn of the century.

Primary production of industrial roundwood was 74 million m^3 in 1950, at which time hardwoods accounted for 5 million m^3 or about 7% of the total. In 1989, the total harvest was approximately 186 million m^3. Hardwoods accounted for around 13 million m^3 or about 7% of the total. Fuelwood production was 7-8 million m^3, but this will not be included in the analysis.

Since 1950, roundwood production shares by region have shifted away from Quebec and the Atlantic provinces in favour of British Columbia (Table 1). The shares of the Prairie provinces and Ontario are relatively unchanged.

The product mix has shifted markedly since 1950, with lumber and other solid wood products increasing their share of roundwood use from 55 to 75%. This reflects major expansion of the sawmill sector in the British Columbia Interior and heavy investment in lumber production east of the Rocky Mountains. At the same time, major forest products have exhibited the following annual rates of growth in output:

Lumber	3.5%
Wood based panels	7.4%
Wood pulp	2.9%
Newsprint	1.9%
Other paper and board	3.9%

Table 1. Industrial roundwood output shares by province and region (per cent)

	1950	1986
British Columbia	27.6	46.4
Prairies	8.4	9.1
Ontario	17.1	16.7
Qubec	32.4	19.4
Atlantic	14.5	8.4
	100.0	100.0

Source: Statistics Canada 1960, 1989.

The growth of wood based panels has now tapered off from a four decade rate of 7.4% annually to a modest 2.3% over the last decade, whereas lumber has fallen to 2.8%. Meanwhile, higher value book and writing paper has been growing at more than 9%. Unfortunately, there are no published data on the sharp surge in higher valued solid wood products that we understand has taken place.

The contribution of the forest sector to the Canadian economy needs to be underscored. First, the selling value of shipments is now reported in the monthly "Survey of Manufacturing" to be over $40 billion annually. This compares with farm cash receipts of $22 billion. Second, the export value of forest products reached $22.6 billion in 1989.

The third measure to emphasize is forest sector employment. The forest industry employed 349 000 individuals in 1989, according to Statistics Canada. This figure is taken from the "Labour Force Survey" and is considerably higher than the 270 000 quoted in Forestry Canada (1990). The lower figure appears to originate from a 1986 "Census of Manufacturers" survey. It is apparent that the forest industry has now largely recovered from employment losses suffered during the early 1980s.

Some readers will have noticed the absence, to this point, of any mention of nontimber values. The reason is not that they are regarded as being unimportant. On the contrary, but historical data have not been assembled on a Canada-wide basis. However, nontimber values will be discussed later in a crude attempt to indicate future directions.

Method and Assumptions

Before forecasting timber availability to 2050, let us turn briefly to methods and assumptions that govern the direction and magnitude of changes in timber supplies.

It has been rumoured in the *Vancouver Province* that I "depend heavily on a marvelously optimistic computer." I am certainly optimistic, but the truth is that I do not use a computer for timber supply projections. Many companies do so and some provinces are now very skilled in computer simulation of growth and yield. But there is no computer analysis of Canada's timber supply outlook that covers the entire country in a consistent and credible way, and certainly nothing is available that extends forward for 60 years.

This means that we still have to rely on what used to be called judgmental extrapolation, an art that is much less arcane than computer science, but suitable nevertheless to the purposes of this paper. Those with long experience in timber supply analysis can become quite good at projecting ahead on an intuitive basis.

The difficult part of projecting forward over lengthy periods is knowing what assumptions are likely to be critical in the long run and then being explicit about their use. I have selected 12 assumptions and will indicate the impact they are most likely to have in coming decades.

Market Trends

The most authoritative assessment of markets for forest products on a world scale is conducted by the Food and Agriculture Organization of the United Nations (FAO) in Rome. Their latest world outlook projections were published in 1988. Consumption totals for the major commodity groups are shown in Table 2, together with average annual rates of growth for the years 1986-2000. These data indicate a buoyant market for the major commodity groups. During the 14 year period to 2000, increases in volume will continue to mount, and annual rates of change will hold up reasonably well in relation to the recent past.

It would be reassuring to have global projections further into the future. For example, the Economic Commission for Europe (ECE)-FAO in Geneva has projected timber fellings to the year 2020 and the United States Forest Service has already published data for the year 2040. Even in the absence of benchmark studies, I believe that it would be prudent for planning purposes to assume that consumption trends will continue to advance, along with world population and income. In contrast, it is the timber supply side that is more likely to act as a braking device with respect to future development potential. This will be obvious as the next set of assumptions are noted.

Product Mix

Having over 40 years experience in the forest sector gives one some basis for believing in the adaptability of our entrepreneurs and in the relatively slow pace of new product development. For instance, none of the major fears we discussed around 1950 have turned out

Table 2. Consumption trends and projections of forest products

	Actual		Projected	Annual Rate
	1975	1986	2000	1986-2000
Solid wood products (million m^3)				
Industrial roundwood	1293	1580	2077	2.0
Lumber	404	475	589	1.5
Wood based panels	84	119	203	3.9
Fibre products (million t)				
Wood pulp	97	136	186	2.3
Newsprint	21	29	42	2.7
Printing and writing	28	55	95	4.0
Other paper and bond	82	118	157	2.1

Source: FAO, Rome, Report No. 84, 1988.

to be critical. Our customers have a continuing attachment to lumber, newsprint, and other traditional paper products. It appears sensible in 1990 to approach the future in the belief that our inventiveness has not expired. That does not mean that we should close our minds to possible changes in product mix, but should instead keep our options open with respect to the range of timber specifications we might be called on to produce. To those who say that two-by-fours are obsolete, and that fibre products will increasingly dominate, I respond simply, "Don't be too quick to judge."

Prices

Whether we use computer simulation or not, it is usually assumed that the marketplace will balance supply and demand when given the necessary time to function. It is my opinion that shortages of prime timber are already being expressed in higher real prices. Cost-saving technology can postpone price changes for a period of time, but sooner or later the upward pressure will be felt. Average prices and average stumpage costs may appear stable, but when quality aspects are considered, there is or soon will be a price escalation for individual grades and species. In the case of delivered wood costs, the second crop of timber would normally be much lower than the first. However, stricter logging guidelines, higher silviculture costs, increases in stumpage, and other factors will surely force roundwood prices to higher levels.

Foreign Competition

The ability of Canadian forest companies to compete in foreign markets will be influenced by exchange rates and the relative rates of cost inflation. The industry has a fair degree of control over most of its costs, but exchange rates are another matter entirely. The combination of an overvalued Canadian dollar and high interest charges is completely beyond the industry's control.

My own view is that our dollar will eventually drop below 80 US cents, and that the current interest rate penalty of 5-6% above the United States will not continue for long. These two items have already offset any gains our exporters might have enjoyed from the Free Trade Agreement.

Falldown

This has become a common term in Canadian forestry circles, even though its meaning is ambiguous. The falldown is essentially a reduction in available timber supply volumes that results from two propositions. The first is that a timber crop that has taken several hundred years to grow is likely to yield more merchantable volume at harvest than a second and shorter rotation will provide. If we accept this line of thinking, there is likely to be less volume available as we work through the transition to harvesting second growth.

It is my personal view that this volume falldown is overstated, largely because the growth and yield projections imbedded in our estimates of annual allowable cut are still based largely on unmanaged stands and on-site class indices that are excessively conservative. Moreover, it is now recognized that intensively managed forests will often produce a larger volume of merchantable timber in a shorter time than that available from virgin stands.

The second falldown proposition is that the operable margin is more restricted than was thought earlier due to the deletion of uneconomic stands, environmentally sensitive sites, wildlife reserves, and so on.

This volume loss is too obvious to require elaboration. In addition to this falldown in volume is an equally serious drop in value as we enter stands with a less attractive species, a lower grade mix, and smaller logs. This is already in evidence across Canada and the forest industry will have to be very inventive to cope with this situation.

Reservation of Industrial Forests

There is a major campaign under way, especially in British Columbia and Ontario, to set aside forests for wilderness, ecological reserves, parks, wildlife, scenic corridors, and other single uses. The preservationists have been very effective over the last decade. About 6% of Canada's land is now reserved, and there is a concerted move under way to double this share. However, the demands on mature forests are often much more aggressive. Some individuals and groups are calling for a complete halt to logging in old growth, which means at minimum the very best of the high quality old growth that remains in industry licences, and possibly much of the average forest as well.

A related factor is aboriginal land claims. Some Indian bands have said that they would cancel existing forest licences, others have declared to favour permanent wilderness or recreation status, and most would likely require the adoption of new logging techniques. We can assume that a combination of reallocation and land claims will reduce existing available industrial timber by at least 10% of available volume over the forecast period, that the quality falldown will be serious, and that much of this will be on the better growing sites. I still believe that Canadians are capable of reaching a consensus on these issues.

Logging Guidelines

We can also anticipate more restrictive guidelines on clear-cutting and logging methods. Calls for selective logging are growing more insistent. Changes will be imposed on both public and private lands. Within a few years, it is likely that most provinces will enact forest practices legislation.

For whatever reason, the end result will be to shrink the margin of economic supply. Recently, I heard someone speak about a recipe for "new forestry." There was a beguiling plausibility to much of it until the speaker was asked what the impact would be on the forest sector. The answer was roughly as follows: "New forestry" would leave behind 15% or more of the volume, an amount equivalent to 20-25% of the value, and an increase in logging costs of 10-20%. Provincial forestland use policy formulation would be foolish to ignore the potential dislocation this would cause.

Environmental Policies

Federal and provincial governments are imposing major changes with respect to effluent regulation and toxicity control. These are compounded by paper recycling demands. The result will be a major capital cost burden on the order of $10 billion over the period 1988-1993. Annual operating costs will also rise sharply. If our governments decide to move forward well in advance of competing countries, as they appear to be doing, we will suffer a temporary reduction in competitive vigour. It seems likely, however, that the international balance will be restored within a decade.

Air Pollution

A consensus appears to be building that the mixed wood and hardwood forests of south-central Canada and the Maritimes are being impacted negatively, though the magnitude has not really been tied down. In addition, it appears that internal combustion engines are more of a problem than heavy industry. The northern boreal forests seem to be relatively free from damage.

Global Warming

It is extremely difficult to separate the true risk to vegetation from the political hype and emotional claims. In my view, too little is known about the capacity of oceans and soils to sequester carbon, about the compensating effects of heavier cloud layers, and about the validity of global circulation models, which deal poorly with such variables. In a single weekend recently, the media ran stories stating that circulation model projections were quite unreliable, along with contrasting reports that the jury was in on the side of near catastrophic warming. It is virtually impossible for the layperson to separate the facts from the "chicken little" syndrome.

Intensive Silviculture

Is it really as bleak as the foregoing constraints might suggest? My response to the pessimists is that Canadian land managers are going to do what the Scandinavians did right after World War II. They knew that they were faced with a problem and they began to manage intensively, and so will we. Moreover, progressive foresters in other countries have often assured me that they would be growing twice as much if they were in charge of our forests.

Two factors must be kept in mind at this juncture. First, it is now mandatory to regenerate cutovers promptly, it is no longer a discretionary investment in the traditional sense. Second, intensive silviculture, by which I mean the treatment of middle-aged stands, appears to offer a very positive rate of return in widely varied situations. This will be discussed later.

Similar Problems Elsewhere

It is essential that our appraisal of Canadian problems be seen in relation to those experienced elsewhere. For example, the preservation movement is stronger in the United States and is continuing to build momentum. A campaign is under way to halt logging completely on United States federal lands, and private lands are experiencing a new and harsher regulatory climate. In addition, the majority of small private forests in the United States are not being managed at all. The result is heavy upward pressure on stumpage and other costs as well as the curtailment of industry access to millions of hectares of mature forests.

Forest companies in other countries are also facing new costs. To illustrate, the rapid phasing out of nuclear power in Sweden could add 50% to their power costs, which are already one-third higher than Canadian levels.

These dozen assumptions may appear rather subjective to some readers, and that may well be the case. On balance, I believe the Canadian forest sector will not find its competitive position eroded in a serious and permanent way. The largest threat I perceive is the lack of commitment to a higher level of stewardship of our forest resources. Even there I remain optimistic.

Industrial Timber Outlook

The departure point for a forecast to 2050 is the current level of harvest. The latest published information for all provinces is based on 1986 data (Forestry Canada 1989) and I have estimated 1989 data by contacting the provinces. The totals are 173 million m^3 and 13 million m^3, respectively, for and hardwood species. Based on solid wood and wood fibre products and other information for the years 1988 and 1989, the output may have dropped back by 2-3 million m^3 of softwood from the 1987 peak of 175 million m^3, while gaining a couple of million cubic metres of hardwood.

Alongside the timber harvest, we would normally show provincial annual allowable cuts (AACs). The aggregate of the AACs for softwood species is somewhere between 165 and 170 million m^3, depending on how we wish to handle temporary salvage sales; anticipated near-term reductions in some remote timber supply areas that do not have roads; and imminent reductions in AACs due to sawlog shortages, new logging guidelines, and decisions on preservation.

On a Canada-wide basis, we are now harvesting annually slightly more than the softwood AAC, as shown in Table 3. This is clearly the case in British Columbia, although the excess cut does not arise from regulated Crown land but from unregulated private forests. Last year, some 13 million m^3 was harvested from private lands, although an imputed AAC would likely be 5 million m^3 or less. There is said to be excess capacity in the sawmill industry on the coast of 30-40% according to industry officials, and the British Columbia Interior lumber sector is also overbuilt.

Alberta has a surplus of softwood AAC over harvest of about 4 million m^3, but the majority of this is committed to new pulp mill ventures. However, there are soft spots in sawlog supplies along the east slope of the Rocky Mountains. Saskatchewan has serious sawlog problems and is expected to announce curtailment of sawmill operations in the near future. Manitoba has a surplus of perhaps 2-3 million m^3 of uncommitted softwood, but those stands are economically inaccessible for the most part.

Ontario is experiencing shortages of quality sawlog material and even pulp and paper mills are hauling pulpwood hundreds of kilometres in some cases. Data on both harvest levels and AACs are difficult to es-

Table 3. Comparison of the AAC and harvest in 1989 by province or region and species

	(million m^3)			
	Softwood		Hardwood	
	AAC	Harvest	AAC	Harvest
British Columbia	77	87		
Alberta, Saskatchewan, and Manitoba	23	14		
Ontario	25	24		
Quebec	31	33		
Atlantic provinces	14	15		
	170	173	60	13

Source: Estimated from published sources and personal contacts.

timate, largely because of the meagre data available from private forest owners. What appears on the basis of 1989 estimates to be a surplus of AAC over harvest is now regarded by many as doubtful, although there is little public discussion of this. The Temagami area is an exception.

The province of Quebec has problems similar to those of Ontario. Substantial areas of the uninhabited pulpwood zone are inoperable. In addition, there is a consensus in industry and government that a reduction in sawn lumber production of 20% is just a matter of time. Their lumber producers rely on imports of sawlogs of about 3 million m^3 annually, the majority of this coming from the United States. Part of the problem relates to the heavy overcommitment of forests on private lands in the commuter zones.

The Atlantic provinces have been working hard to overcome softwood shortages for a decade or more. New Brunswick discovered in the 1970s that it had excess capacity of around 10% and has been working assiduously to rebuild its forest potential. Nova Scotia has a shortage of sawlogs, although it has a temporary surplus of pulpwood, which is likely to evaporate around the turn of the century. Prince Edward Island is likewise addressing a degraded forest by sponsoring aggressive silviculture programs. Newfoundland has a manufacturing capacity 25% greater than the sustainable harvest and is struggling with a strategy to overcome the deficit.

On balance, one is justified in questioning the validity of Canada's softwood AACs as presently estimated, given gaps in mature and near-mature age classes as well as the limited amount of intensive forestry now being practiced.

As far as hardwoods are concerned, the present harvest of 13 million m^3 compares with an aggregate AAC of approximately 60 million m^3. When the present surge in hardwood pulping capacity is on stream, especially in the Prairie provinces, it is likely that the harvest will approach 15 million m^3.

Before making the forecast to 2050, it is necessary to point out that prudent corporations are busily canvassing their options for balancing timber supply and demand. Some individuals have told me, "Forget about this province." And some have even said, "Forget about expanding in Canada, we intend to invest elsewhere." I do not believe this pessimism is widespread. In fact, there are numerous feasibility studies under way at present collecting data for inputting into long-term strategic planning. Ten of the more obvious balancing factors are listed below.

1. Practice closer utilization of standing timber
2. Reduce logging waste
3. Begin commercial thinning
4. Use more sawdust and shavings in wood pulp
5. Recycle wastepaper
6. Chip economy lumber
7. Reduce exports of logs and chips
8. Enhance protection against fire and insects
9. Adopt new technology
10. Manage forests intensively

Manage Forests Intensively

Companies have begun to move in this direction already and we can expect a good deal more action. It is necessary to say, however, that the first five items will involve potential reductions in raw material and product quality. All of the options listed will be costly. In the case of intensive forestry, however, I believe the benefits will often exceed the costs by an attractive margin.

It is timely to digress here with a short comment on intensive forestry, by which I mean precommercial thinning, fertilizing, and pruning. Some individuals might like to add the introduction of genetically improved planting stock, commercial thinning, or other items to the list. An orderly examination of the benefits of intensive silviculture will embrace a number of factors that traditional forest economics has ignored.

A wide range of forest level benefits are identified in Table 4. This schedule speaks for itself. The key for those companies and communities threatened with an early falldown in timber supply is item 2. Decreasing the time to operability and especially sawlog diameters can often be achieved by moving stands forward in the harvesting queue by 10-20 years or more. This action should help materially to mitigate timber deficits.

These benefits are of equal interest to both provincial and federal governments, as well as to those Canadians attracted primarily to nontimber values listed as items 6, 7, and 8.

Finally, the forecasts for softwood and hardwood species are shown in Table 5. These are not ambitious in terms of market potential. I have indicated a mere doubling in the availability of softwood roundwood in 2050, which is far short of the postwar consumption trend. This implies an annual rate of change for Canada of 1.16%. For hardwoods, I see a fourfold increase. The total for all of Canada, therefore, would increase from 186 to 400 million m^3. This implies an annual increase of only 1.26% compared with a 2% trend projected by FAO. I see no reason why all regions cannot share in the development potential in these projections.

It may be worth pausing here to point out that there are usually three types of projections. The first is the higher one and considers only *biology*, or the capability of the land to produce under intensive

Table 4. Forest level benefits from intensive management

1. Harvest volume increase from the forest as a whole
2. Shorter time to stand operability and sawlog diameters
3. Cost reductions
    a. shorten hauling distance
        - by treating land near the mill
    b. produce larger, more uniform logs
        - for logging cost savings
        - for lower processing costs
4. Value gains
    a. species mix improved
    b. lumber recovery factor raised
    c. grade and dimension mix enhanced
    d. residual chip values increased
5. Risk reduction
    a. insect and fire losses reduced
    b. less reliance on open market
        - for logs
        - for pulp chips
    c. less risk of curtailment from timber shortage
6. Release of forestland for other uses
7. Improving the recreation value of forestland
8. Net improvement in wildlife habitat

Source: Reed and Baskerville, 1990.

management. The second is a *policy* projection, which is what a visionary person or a politician would like to see happen. The third is a *reality* projection, a figure that takes into account the realities of a technical, financial, and institutional nature.

My projection for 2050 is closer to a reality target, although it may appear to some individuals to be visionary in character. With this long-term horizon in mind, we can choose our future in forestry. I sincerely believe this to be the case. Incidentally, a reality target such as the above could easily be demonstrated by a computer simulation of timber availability. For example, you might ask the computer to suggest the least cost silviculture regime or the expected cost to produce a sawlog volume of a specified quality.

It is also worth noting that the harvest projection of some 400 million m^3 in the year 2050 easily passes the test of plausibility. The present aggregate of the provincial AACs is 230 million m^3, compared with the related 212 million ha of productive, nonreserved forestland. This implies an average growth rate of only 1.1 m^3•ha^{-1}•year^{-1}. The projected harvest of 400 million m^3 from the same land base works out to an average of 1.9 m^3•ha^{-1}•year^{-1}.

In contrast to these somewhat timid expectations, one could point to evidence in various regions of Canada where even modest silviculture efforts, mainly thinning regimes, are producing much more than this. For example, in the Malcolm Knapp Research Forest at Haney, British Columbia, the documented mean annual increment in hemlock and Douglas fir is approximately 15 m^3/ha; in the Kirkwood plantations near Thessalon, Ontario, red pine is recording 10-12 m^3/ha; and in the

Table 5. A new vision of forest stewardship for Canada

	1950	1989	2050	Per cent Annually
Annual Harvest (million m^3)				
Softwood	69	173	350	1.16
Hardwood	5	13	50	2.23
	74	186	400	1.26
Annual Harvest/Use				
Fish	?	?	?)	1-3 ??
Wildlife	?	?	?)	
Recreation	?	?	?)	
Wilderness	?	?	?)	

Green River spruce trials in New Brunswick, the mean annual increment is 10 m^3/ha. These are not average growing sites in Canada, but neither are they managed intensively by Scandinavian, New Zealand, or United States standards.

In short, my mistake is not in suggesting a target that is too high, but in setting one that may turn out to be ridiculously low. My only excuse is that a higher projection would be more of a challenge than most Canadian forestland managers could probably handle.

Nontimber Values

It was my intention to provide a broad estimate of the direction in which the use and enjoyment of nontimber values seem to be headed. The almost complete lack of an information base, however, has forced me to limit this section to a few lines.

The first comment is that no projection of industrial timber harvest has any validity unless there is an explicit recognition of the other vital resources associated with forestland. I speak of fish, wildlife, recreation and tourism, wilderness, watershed protection, heritage values, ecological uniqueness, viewscapes, and so on. These are the elements that contribute so profoundly to the life-style and psyche of all Canadians.

Unfortunately, we have no historic trends to suggest the magnitudes of change and of current use, and this makes it virtually impossible to forecast the next decade, let alone the next six decades. We can assume that the annual rate of change will vary considerably among the items listed. In Table 5, they are shown with a purely notional annual gain of 1-3%. Some concentrated work needs to be done on these numbers without delay.

The second comment deals with the principle of integrated resource management. I addressed the issue along the following lines in a recent brief to the British Columbia Forest Resources Commission (Reed 1990). Can we accomplish the above without impairing the fresh water, the forest soils, the clean air, and other nonconsumptive values associated with forestland? Can we do so along with full regard for native people, biological diversity, and historic landmarks? My answer is an emphatic yes. The technology to manage timber and other forest resource values is now being demonstrated both here and elsewhere. More importantly, the custodial instincts of our citizens are maturing rapidly. They expect more and the quicker we get down to consensus building, the less it will cost.

Implications for Policy

What I have been discussing is now called sustainable development. What are the related implications for policy and planning? The first is the urgent need to crystallize a vision for the conservation, wise use, and enjoyment of the forest, and I include preservation in the list of uses. The second implication is that we had best get on with a stewardship program. The vision sets out our aspirations and stewardship will take us there. True stewardship seeks to enhance resources, not just to maintain them. Third, sustained yield is a tired and excessively conservative concept with too many shades of meaning. Its usefulness has been eroded by redefinition to include falldown. It is time we set our sights on expanded yield. A shrewd investment in stewardship will surely enhance the magnitude and quality of our resources, thereby vastly improving our range of choices. Fourth, there are cost implications for everyone involved. There is no point in suggesting that industry will shoulder the bills because they will eventually pass the costs on to their customers or suppliers, or perhaps they will disinvest in the forest sector. Governments do not have any money except what they take from taxpayers, so we might as well concede that ordinary citizens will pay for sustainable development out of their own pockets. A fifth implication, as yet undefined, is the role of the professional, whether in forestry or some other field. I simply observe that universities are a bit confused on how to handle this issue, and that this confusion may have played a significant part in setting up and prolonging the confrontation in society over land use. Sixth, the resource inventory is terribly deficient. This ought to be the easiest problem to fix because everyone agrees that the system is deficient. Leadership rests with governments on this issue, and I would point the finger first at Forestry Canada.

Reflections

There are probably many individuals who have grown accustomed to and even comfortable with pessimistic timber supply scenarios. There may be others who were taught more recently that falldowns are inevitable, and that efforts to mitigate these are at best ill-considered.

My answer is taken from a line by Will (1983) who referred to another policy as both "intellectually idle and politically feckless." The way I read the public's mood is that falldowns will not be tolerated by them or by their elected representatives. Similarly, the intellectual sterility of policy analysis is nowhere more pronounced than in the field of stewardship of our forest resources. Those who counsel the status quo, or worse, will not survive the legitimate criticism of informed citizens and the sooner their views are discarded the better.

I mentioned earlier Canada's destiny as a forest nation and invite readers to reflect on this. As we repair our forest policies and practices, may you dream of a richer life as well as a better one.

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Integrated Management of Forest Resources

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Abstract

The forest industry in Quebec is currently undergoing a radical transformation in the approach that must be taken to manage the different forest resources. To maintain sustainable development of the industry, new frames of reference are being established, work techniques are being modified, and priorities are being established to put the land base back into production. A concerted effort by those working in the field is the only way to achieve sustainable development.

Résumé

L'industrie forestière québécoise transforme actuellement de façon radicale son approche à l'aménagement de différentes ressources forestières. Afin d'assurer un développement durable de l'industrie, de nouveaux cadres de référence sont établis, des modifications aux techniques de travail et à l'ordre de priorité doivent être apportées afin de remettre les terres en production. La concertation de tous les intervenants dans le domaine est la seule façon proactive d'arriver à un développement durable.

Introduction

Over the past few years, the forestry industry, provincial forestry ministries, and the federal government have come to understand the importance of their role in the development of the forest resource. Along with this first step, they have also come to understand the complexity of the task awaiting them, whether it is the development of the forestry industry, the pluralistic use of land whose primary use is for forestry, an understanding of the different forestry-based resources, research and technology transfer, or the lack of recognition by the public for the management efforts and improvements put forward related to our different forestry resources. In the past, forestry managers in different regions of the country have not shared in their decisions and approaches. A new era is upon us, however, and we are now beset with the problem of how to manage our forest resources.

The Province of Quebec is no Different than the Other Canadian Provinces

The Great Administrative Eras

From the era of the forest lookers or timber cutters until 1972 was the time of the big forest concessionaires who were responsible for forest and territorial management. According to this system, forest licensees had to manage, under a sustained yield, the different sectors that they had been assigned. The government, for its part, had to control the quality of the work that was done and had to ensure that obligations under the different licences were met. In 1972, following the tabling of a white paper on forestry policy, the government took back responsibility for forest management and for allocating the different forest resources. Because they no longer had territorial responsibilities, former licensees sent some of their employees on to other jobs.

To achieve maximum utilization of forest resources during this period, major expansion took place within the sawmill industry in Quebec and, to a smaller extent, within the pulp and paper industry. After a few years of this type of development, the industry found that it had a level of harvest that was much greater than the actual capacity of the forest. Not all of the province's regions found themselves in this situation, but the annual allowable cut was diminished. It is important to note that at the same time, the province was experiencing an infestation of spruce budworm (*Choristoneura fumiferana* (Clem)) and that efforts were being made to recover as much of the wood being destroyed as possible.

Faced with the inability of the government to adapt itself to efficiently managing the different forest management units, the Quebec government radically changed direction in 1987. When it started applying Bill 150 on April 1, 1987, the Ministère de l'Energie et des Ressources returned responsibility for forest management and maintenance of annual allowable cuts to the forestry industry. After a 3 year transition period, each company is now responsible for a licence area. As for the government, its role will be one of planning, controlling, and coordinating the activities of the different players involved.

These changes have modified the approach we must use as managers of the forest. As such, we have made the transition from exclusive utilization of the forest for the production of wood to pluralistic utilization of a forest whose primary function is the production of wood. Having tabled three successive laws amending Bill 150 in less than 3 years has resulted in a period of harmful administrative instability in the forestry sector. Regrettably, administrative and contractual uncertainty also exists among the different people involved at the forest management level.

Hopefully, we will not have to endure the tabling of bills year after year and that certain modifications will be brought to this approach.

History of the Forest Situation in Quebec

The forestry sector of Quebec is currently in a very difficult position and steps must be taken to restore the vigour that characterized it for so many years. Until 1972, it was estimated that the forest's production capacity for softwood species was about 27 million m^3 annually. However, a severe infestation of spruce budworm eliminated approximately one third of the softwood timber stock within 15 years. A large portion of mature fir and white spruce stands were then infested, which has resulted in reducing the current annual allowable cut to about 18 million m^3.

As for the hardwood forest, its production capacity has remained relatively constant over time. A large portion of the hardwood forest, however, continues to be of very poor quality. This situation is attributable, for the most part, to the different stand management methods used and the lack of silvicultural input. Very important changes in management regions must be made and we must accept that for a relatively long period of time, recovery work will need to be carried out.

New "contrats d'approvisionnements et d'aménagements forestiers (CAAF)" (Supply and Management Contracts)

Without going into too much detail, "contrats d'approvisionnements et d'aménagements forestiers" place upon each company concerned responsibility for managing a specific licence area and ensuring that the mill's wood supply is maintained under sustained yield. Quebec's system is somewhat peculiar in that for the same common area, there can be several companies, each with a CAAF. All of the beneficiaries together will designate an agent who will be responsible, under contract, for the harvesting operations and silvicultural work required under the CAAF on the common area. The agent will select the species and quality of logs requested by each beneficiary.

Each company was allocated a sufficient area to manage jointly with the other beneficiaries according to silvicultural ground rules included in the CAAF. These rules are designed to maintain sustained yield of all of the species. As with many other systems, standard reductions were used to take into account different exploitation methods, levels of decay, loses due to fire and insects, and all kinds of land base withdrawals.

The contract presented to the companies is for 25 years, renewable every 5 years, on a perpetual basis. To start the initial process and the 5 year renewal, general orientation plans, 5 year silvicultural plans, and main infrastructure plans must be prepared according to specific guidelines established by the government. Before they are approved by the government, the different plans must be the subject of public consultation, whereupon all interested parties can consult the documents and discuss their contents.

The volume allocated to each company was determined using the 1982-1987 period as a reference. This analysis was completed for all companies to constitute a regional file on the demand for wood from the public forest.

At the same time this evaluation concerning the offer for wood was under way, forest yield was being quantified following seven steps:

1. Analysis of inventory data stratification
2. Inventory data update
3. Allotment of territory and definition of territories for yield calculations
4. Hypotheses regarding the general evolution of each forest type
5. Hypotheses regarding spruce budworm decay, the impact of harvest methods, and other reductions
6. Grow forest types over time
7. Calculation of annual allowable cuts by species or groups of species and quality.

Sustained yield was calculated with the help of a computer program called "SYLVA," a system based on "area multiplied by average yield at rotation." It is clear that this system only evaluates the annual yield of fibre, without taking into account the quality of the wood. Moreover, it does not take into account the spatial distribution of the different mature stands to be harvested and of the existing road network. Because it was built according to a closed architecture, logical selection of harvest blocks cannot be made. With respect to utilizing SYLVA to calculate forest yield in hardwood, I also believe that the model is flawed.

Before a company is allotted its final volume, all other supply sources will be taken into account so that it is only given a residual supply from public forests.

How Will We Reconcile Sustained Yield and Sustainable Development?

When the possibility of a territorial forest was first considered, one of the steps taken involved analyzing the territories to be retained for forest production and for calculating sustained yield.

Sustainable Development

When the territories to be retained for timber production are being identified, wood supply analyses must be conducted according to the integrated principles of managing the different forest resources in the area. Obviously, certain political choices must be made at the regional level to identify production priorities in the different zones. It remains to be seen whether it is possible to take on integrated forest management, while allocating harvest rights on a priority basis, without harming wildlife habitat, the recreation industry, or native lifestyles. Integration of the different uses of a territory must be made in a proactive manner by each of the stakeholders because in this way it is possible to function in harmony.

The forestry industry can be integrated into the management of Virginia deer as was done for moose and other species. For example, in Armstrong, 70 km from Québec City, the forest society has significantly influenced the growth of the Virginia deer population, which saw the size of its herd quadruple in 3 years through the timing and choice of cutting methods used by the people involved. This shows that integrated management is possible. This case illustrates that the forest industry can make room for wildlife. Furthermore, it is also possible for the recreation and fishing industries to exist together with the forest industry and to ensure a basis for sustainable development through joint utilization of access infrastructures and through adequate protection of the environment. We need to refer to the "Modalités d'intervention en milieu forestier" (Methods of intervention in the forest), which was adopted in Quebec by regulation and was the object of a consensus among the three major ministries in this sector:

- Ministère de l'Energie et des Ressources (Energy and Resources)
- Ministère du Loisir, de la Chasse et de la Pêche (Recreation, Hunting and Fishing)
- Ministère de l'Environnement (Environment)

With respect to natives living on the different territories, a process of regional consultation and exchange must be put into place to clearly identify the priorities of each of the groups concerned. This can include trap lines, hunting encampments, wildlife habitat, and berry harvesting practices. It is important to know the objectives of each of the bands and to integrate their ancestral customs.

It is obvious that integrated development of these resources does not constitute a simple matter, but a difficult exercise in rationalizing everyone's ideas and priorities. This must be done, however, if we want sustainable management of the different resources.

Sustained Development

If industry and government are to ensure sustained development of the Canadian forestry industry, decision makers will have to be proactive in dealing with problems that will be encountered. The timber cruiser era is now over and we are in the 1990s. The population's mentality has changed and ordinary people want to be involved in decisions that concern them. That is why a regional consultation process must be put in place to inform people of the choices and orientations that will need to be made. Only through such a process can we ensure a level of harvesting adapted to all users needs, either directly or indirectly.

In the year 2050, communities' preoccupations will probably differ from those of today, but we must not lose sight of the fact that in a mere 60 years, only 50% of the rotation of our forest will have been completed. It can be foreseen that the quality of the environment and the protection of wildlife habitat will continue to be a subject of public debate because new priorities will always confront the needs of the industry.

How Will Quebec's Forest Industry be Able to Reach Reconciliation and Meet Its Objectives?

Reaching social and industrial objectives can no longer be considered separately as it was in the past. An integrated approach must be taken and our planning system must be modified to solve these new problems.

Public Consultation Process

The results of the 1989 Environics survey clearly showed that public opinion is very negative with respect to the ability of industry and government to manage our forest heritage. Because the forest is largely public property, people are developing a sense of responsibility towards the protection and utilization of forest resources.

To modify this tendency and to ensure that it is, in fact, possible to practice integrated resource management while withdrawing an industrial wood supply, a provincial process of public consultation must be started so that society as a whole can make some decisions. Thus, a "strategy for the protection of forests" must be developed whose main objectives would be

- Maintaining yield and existing socioeconomic activities
- Respecting the environment's biophysical components
- Minimizing (and eliminating if possible) the use of pesticides in our forests

This should provide a framework within which forest management can be designed according to ecological principles, but still moving towards normalizing our forests.

Local Public Consultation Process

After being awarded a CAAF, each company will prepare, during the months following its acceptance, a forest management action plan showing the general pattern of harvesting, the location of silvicultural treatments, and the infrastructure to ensure these plans are realized. A portion of the general plan will need to be included in the 5 year plan and show, in detail, the different strategies that will be used to improve the licence area. It is clear that these strategies will need to be in line with the objectives previously described.

To integrate the regional concern groups, a local public consultation process will need to be put in place to ensure that forest development will be in keeping with the other uses.

Setting Up Data Bases for Integrated Management Systems

The new direction we are choosing will require the integration of a varied data set with a multitude of positive, negative, restrictive, or less important influences depending on the area concerned. To prepare integrated development plans for the same land base supposes that we have access to very powerful integration tools and that diverse data will somehow be put together. Particular attention will need to be paid to the structure of the data within a geographic information system (GIS), which is an appropriate tool for this type of work.

The extent of the information to be analyzed will need to be limited to a licence area, i.e., 100 000 - 400 000 ha. Working with restricted areas will permit the use of personal computers, the regionalization of decisions, and the maintenance of different data banks.

An important aspect of the structure of the data bases will be the permanence of the fundamental data. Between now and the year 2050, a series of methods will be used, becoming successively more sophisticated over time. Therefore, it is important that the approach chosen will permit the mobility of information with time.

As this integrated data management system is set up, it is hoped that a new open-architecture model for calculations will also be put into place. By working according to an open method, the model for yield calculations could be dynamically connected to a GIS and to optimization systems. By developing these tools, it will be possible to initiate the conciliation between sustained yield and sustainable development.

Models for calculating a more realistic yield from the management of hardwood and mixed forests will also be developed if we function according to an "open" system.

Working with open-architecture simulation models to establish harvest levels supposes that the data bank will be constantly updated with very precise information on silvicultural actions or results. One of the important results of the model will be to establish the soundness of decisions that were taken and to indicate any necessary future changes. This means that precise technical data will be needed by the model, including the following elements:

- Location of harvest area and residual stocking
- Type of silvicultural regimes
- Date of reforestation, species of trees, stocking
- Location and type of precommercial thinning or selective cutting, and characteristics of the residual stands

One can assume that we will be witnessing the emergence of a highly sophisticated forestry data base. However, will we accept the development of a government information system with good global accuracy but that may not correspond to local needs? Will we accept an evaluation conducted by a forest inventory system updated every 10 years and with about 80% accuracy on a local basis such as a licence area? Will any company accept seeing its annual allowable cuts arbitrarily reduced by 10-15% even after having fulfilled its obligations to ensure the maintenance of its level of harvesting. The answer to these questions is negative.

I believe that we need to establish an inventory system in the province of Quebec with two levels of knowledge and two levels of resolution of the results. One, which I will call "intensive," will be composed of all the data compiled by the different agencies. This data base will become increasingly important and will be perpetually updated through land surveys or from data obtained following silvicultural treatments. As for the inventory system, it should be modified to make it more flexible and it should also be continuously updated. In addition, the accuracy of the inventory data should be improved by increasing the number of survey units.

As well as feeding the data base on two levels of resolution, one of which is provincial, data quality must increase. By advocating this type of system, data updating will be continuous and adjustments made for silvicultural programs must also be perpetual to maintain the same level of annual allowable cut.

Finally, very promising new techniques of compiling data are being developed and are on the brink of being usable. By the year 2050, integration of this information will be done automatically, and this discussion will be a thing of the past.

Development of an Ecological Frame of Reference

It is very important that all silvicultural prescriptions and regimes take into account ecological frames of reference that will integrate the following elements:

- soil fertility
- slope
- soil texture
- parent material
- drainage
- aspect

It is hoped that by developing a simple and reliable ecological classification tool, it will be possible to predict the type of regeneration, its dynamics, and its potential growth. Hopefully, the forest inventory system of

Quebec will be adapted to integrate this ecological classification.

Improvement of the Knowledge of Growth and Yield of Forests

Currently, there exists very little information on growth and yield of managed and natural forests and, in particular, plantations and advanced regeneration. Therefore, it is evident that basic hypotheses will need to be verified and rectified as the need arises.

Moreover, there is not a lot of information available on the impact of silvicultural treatments on the future quality of wood. It is evident that all of these studies will need to be carried out within the ecological classification called for above.

Improvement of our Knowledge on Growth and Yield of Deciduous and Mixed Forests

With respect to hardwood forests, the state of our knowledge about the production of quality forests is limited. Companies are concerned about the quality of logs that will come out of deciduous and mixed stands in the future.

Supplies in the Year 2050

For the Industry

It would probably be easier for me to speak about Cascades Inc. rather than other companies. I will try to portray the mills for which I coordinate wood supplies. To begin with, it is certain that by the year 2050, one of the softwood mills will have been using recycled fibres for only 50 years. Because of its location in a deciduous region near an urban area, it will need to take on this new role.

As for the mill that uses poor quality hardwood fibre, the supply of raw materials should not change except for increased competition for this fibre. As for other mills, there should be few changes in supply structure because of their geographic location and the type of wood supplies needed.

For those companies whose mills are far from their supply sources or who are not productive enough, some will shut down their mills and others will open nearer the raw material. Moreover, new facilities will be created whose supplies will be the result of silvicultural treatments that have been practiced intensively since 1980.

In the year 2050, a new forestry era will be possible because 60% of Quebec's forest should be normalized and the level of harvesting should have increased substantially.

Management of Our Resources

Between now and the year 2050, a multitude of changes will be taking place. Initially, there will be a reduction in the annual allowable cut for softwood in Quebec, but the level will increase later. Current forestry data are somewhat optimistic; in time, however, more precise forest mensuration information will correct earlier hypotheses.

It still remains that society must make choices and social agreements related to sustainable development. These will be agreed upon only after regional consultations have taken place. However, we must be conscious that these agreements will need to be perpetually renegotiated according to different local contexts. This is why it is important that a permanent regional dialogue be established and that local decision-makers be empowered to intervene in a proactive manner.

Proper management of the forest can multiply total benefits based on the results of different studies being carried out by the scientific community. Through our efforts towards dialogue, an accelerating effect will be felt from which we can only profit.

Our Profession

I am under the impression that the current state of our knowledge and the complexity of the steps that must be taken will necessitate an increase in technical personnel. Moreover, the complexity of the profession will continue to increase as advanced data processing tools are developed and the need arises to adapt ourselves to these new requirements.

Between now and the year 2050, integrated management of a licence will come into full force, and one of the elements we will benefit from is the wood.

Conclusion

The period of change in which we are living is important. It is not only the data base that must change but also the approaches that will be necessary to fulfill the responsibilities we have to manage all resources. Forest management in the year 2050 will consist not only of managing wood capital but also of managing the whole environment.

The Changing Nature of Annual Allowable Cut and Harvest Forecasting

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Abstract

Traditional calculations of annual allowable cut ignore the interaction between the timber supply and the demand for forest products, and have resulted in some inaccurate perceptions regarding future harvest levels and the sustainability of Canada's forest industry. Supply projections that incorporate the economic dynamics of the resource indicate that there are opportunities for expansion in Canada's forest industry if the demand for Canada's forest products continues to expand.

Résumé

Les méthodes traditionnelles de calcul de la possibilité réalisable annuelle ne tiennent pas compte de l'interaction entre la réserve de bois et la demande de produits forestiers et se sont traduites par certaines perceptions inexactes au sujet des niveaux futurs de récolte et de la capacité de développement de l'industrie forestière canadienne. Les prévisions de l'approvisionnement qui tiennent compte de la dynamique économique de la ressource révèlent que l'industrie forestière canadienne a des possibilités d'expansion à exploiter si la demande pour les produits forestiers canadiens continue d'augmenter.

Background

The forestry handbook I used while attending university lists no less than nine different formulas for calculating annual allowable cut (AAC): simple area, Von Mantel, Hundeshagen, Austrian, Hanzlik, simple increment, inventory control, Brandes' method, and the amortization approach.

It also provides a definition of annual allowable cut that reads as follows (Watts 1983):

> "the average volume that may be harvested annually from a given forest unit which will result in the eventual attainment and perpetuation of an approximately normal distribution of age classes, normal stocking, and sustained yield."

What is especially interesting is that this definition states that the regulatory objective of the AAC is to transform the forest into a normal age distribution. The definition has nothing to say about the economic attractiveness, nor the ecological advisability, of following this course of action. Nevertheless, it is clear that the basic objective to be served is to render the forest capable of supplying a continuous even flow of timber annually, thus matching the material requirements of mills operating as ordinary going concerns.

For more than 40 years, the land management agencies of this country have followed policies aimed at ensuring sustained yield. This has meant that their goal was to have tenure holders harvest the AAC, if not each year, then on average over a number of years. Nevertheless, calculated AACs for the whole of individual provinces have always, until just recently, far exceeded what was actually harvested. There has always been a substantial reserve of AAC on unalienated Crown land for which there has been "no takers." As a result, AAC has never been an accurate indicator of economic wood supplies nor a guide to the volume one could expect to see harvested annually.

This situation has recently undergone substantive change. Not too long ago, no distinction was made by Crown land forest management agencies between that part of the productive forest area that could be said to be attractive for commercial use and that part that was unattractive because of costs associated with access and operations. Today that situation has changed in most jurisdictions, and it is now common practice for forest management agencies to "net-down" the areas of productive forest to what they perceive as being commercially operable, either now or in the near future. British Columbia, for example, currently nets-down what is shown to be its inventoried, nonreserved, productive forest area by slightly more than 50%, i.e., from roughly 49 million ha to under 23 million ha. It is on this "net" land base that the current AAC figure is calculated.

Some indication of the amount of economically unattractive forestland present in Canada's forest inventory can be obtained from the implied rotation periods for each province. These are determined by dividing the area of inventoried, nonreserved, productive forestland by the area reportedly cutover. Figure 1 charts the implied rotations averaged over the last 14 years. The apparent long rotations occur because of the large areas of economically unattractive land included in the forest inventory. Admittedly, account is not taken here of the productive forest areas also "harvested" annually by fire and other natural causes, but one can nonetheless obtain some insight into the substantial net-downs of the productive forest area that must be taking place.

Historically, large areas of forestland that were economically unattractive to harvest in the past have become profitable as economic conditions have changed. Forecasts of future harvest levels that ignore the effects of changing economic conditions on the extent of the forestland base are unlikely to be accurate. Specifically, the concept of consumer demand for forest products

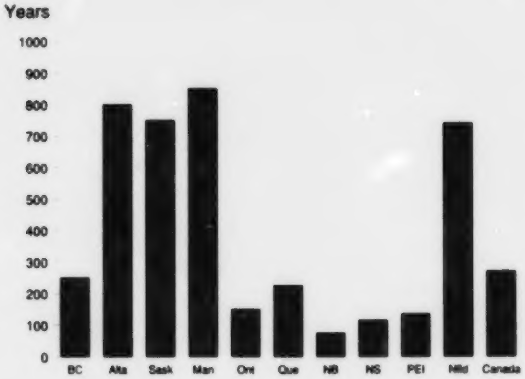

Figure 1. Implied provincial rotations.

and its interaction with harvesting costs experienced on various parts of the forestland base must be incorporated into our harvest forecasting methods.

The Changing Nature of Harvest Forecasting

An early approach to forecasting harvest levels that took consumer demand into consideration is gap analysis. This method endeavours to project past harvest trends to forecast a future production level, often (confusingly) referred to as "demand." This production level is then compared with the likely future physical availability of timber supplies. Where it appears that the physical supply will fall short of the targeted future production level, as shown in Figure 2, an impending gap is proclaimed, and measures (such as intensive management of stands) are advocated to eliminate it. The major shortcoming of gap analysis is that it is not in any way informative about the impacts that different actions may have on ultimate production levels.

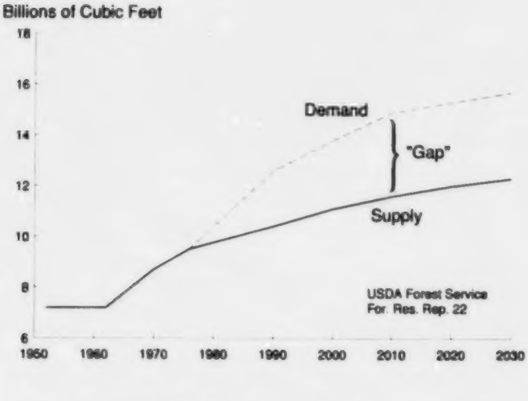

Figure 2. Gap analysis.

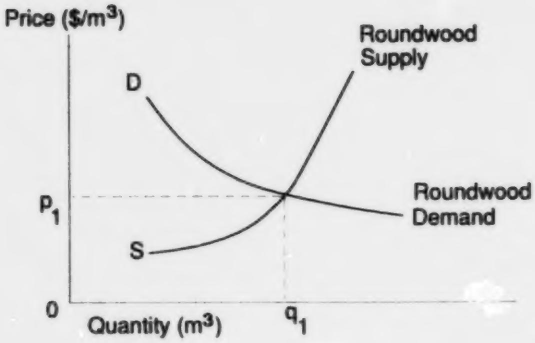

Figure 3. Supply and demand for roundwood.

The interaction between supply and demand is not captured in a gap analysis. What is required is a method that views the quantity consumed as a result of market forces that take into consideration quantities offered for sale at different prices, as well as purchase offers for quantities at those same prices. Both quantities are equal at some unique price that represents an equilibrium point. It is this equilibrium point that establishes the level of consumption (Figure 3) in the supply demand approach to harvest forecasting.

The economic concept of supply/demand equilibrium in price quantity terms offers forestland owners, forestland managers, government policymakers, and researchers alike a useful way to measure the kind of impacts their potential actions are likely to have on future timber production and harvest levels.

Until about 10 years ago, and the development of the timber assessment market model (TAMM) by Adams and Hayes (1980) for the United States Forest Service, it was common practice to ignore supply and demand functional relationships altogether when forecasting future roundwood requirements. Often, a future roundwood production target was set simply as a matter of policy, the strategy being to attain a given level of economic growth and employment.

In 1979, for example, the Canadian Council of Resource and Environment Ministers (CCREM) set out such a policy in Forestry Imperatives for Canada. It articulated the future production choices it saw as follows:

- First, assume that forestry receives no additional investment, and watch the sector decay in one region after another.
- Second, try to double timber production by the end of the century, say by 3-4% annually.
- Third, settle for a 2% growth rate up to the year 2000. This would be lower than the historical rate of the past two decades, but would still increase the annual harvest from 140 to 210 million m³.

It was concluded that the third alternative was the most realistic, and it is beginning to look as if the ministers may be proved right. However, no analytical methods were available to the CCREM to explore either the likelihood of attaining these scenarios or the implications for the timber resource.

AAC Level as a Function of Price: The Price Responsive Timber Supply Model Approach

A number of computer models have been built to simulate growing and harvesting the forest, but few, if any, incorporate the price and cost of delivered roundwood as explanatory variables. For this reason, Forestry Canada in conducting its national timber supply study hired a consultant to develop a model to take these features expressly into account. The output of this project has become known as the price responsive timber supply model (PRTSM) (Williams 1990).

Before conventional economic supply demand analysis could be used to project future supply demand equilibrium points, and associated price and consumption paths, a method had to be found to transform timber inventory data into their annual flow equivalent, assuming sustained yield is adhered to. The calculation of AAC can be shown to accomplish this, permitting the construction of appropriate supply functions for roundwood not only for the current year but also for as many succeeding years as one wishes to look ahead.

The PRTSM constructs a regional timber supply function from timber inventory data in the following way. The inventoried forestland is first stratified into categories in which delivered wood costs are expected to be similar within a narrow range when stands are at harvesting age. Because it is necessary to realistically simulate growing, harvesting, and otherwise depleting stands, all inventory placed in a given delivered wood cost category must exhibit similar growth characteristics. Consequently, it might be necessary to further subdivide the categories in order that the lands assigned to them are similar in terms of both delivered wood cost at rotation age and timber growing capability. Once the inventoried lands have been allocated to the different delivered wood cost categories, the lands within each are treated as separate analysis units. The wood volumes are calculated for each analysis unit and AACs are calculated by whatever method is deemed appropriate.

For instance, in applying the PRTSM in the British Columbia Interior, the region was categorized into eight separate analysis units, and AACs were calculated based on Hanzlik's formula and an assumed 80 year rotation. The AACs for the analysis units were then used to construct a timber supply function for the whole region, as shown in Figure 4.

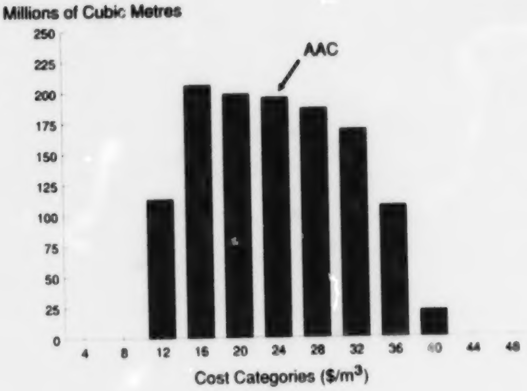

Figure 4. Annual allowable cut by cost category.

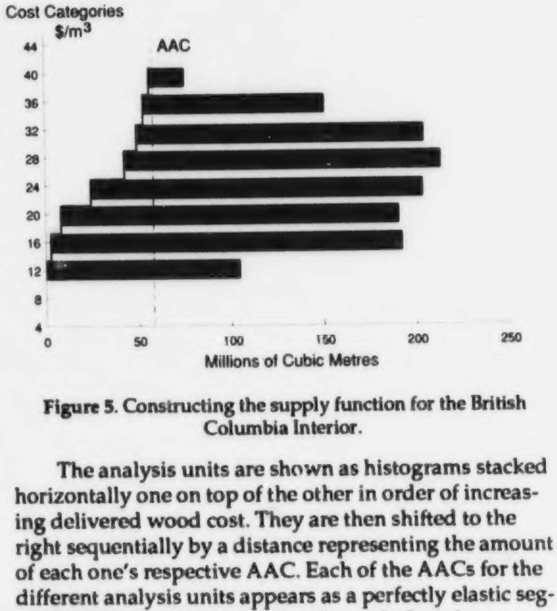

Figure 5. Constructing the supply function for the British Columbia Interior.

The analysis units are shown as histograms stacked horizontally one on top of the other in order of increasing delivered wood cost. They are then shifted to the right sequentially by a distance representing the amount of each one's respective AAC. Each of the AACs for the different analysis units appears as a perfectly elastic segment of the resulting aggregated supply function (Figure 5).

If the horizontal histogram representation of the analysis units is then erased, a conventional "stepped" supply function results, as shown in Figure 6.

By matching an appropriate derived demand function for roundwood with this supply function, a picture of the supply demand relationship in price quantity terms results. Because this is a two-dimensional depiction, it represents the situation for only one year. Figure 7, however, shows supply and demand displayed on a series of frames, each frame representing the particular supply demand situation in consecutive

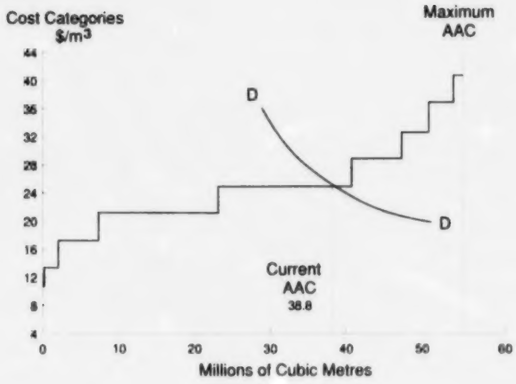

Figure 6. Stepped supply function for the British Columbia Interior.

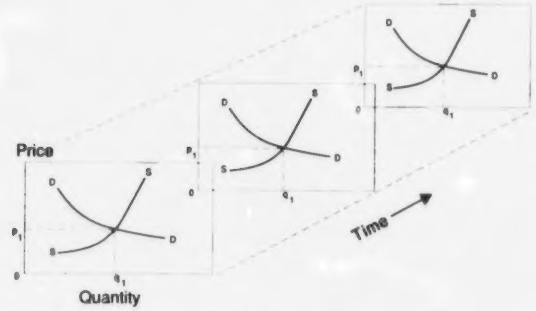

Figure 7. Demand and supply over time.

future years. Future price and consumption paths are traced out by advancing the frames, much like running a video.

A key feature of the PRTSM approach is the ability, when a delivered roundwood price is specified, to determine what part of any old growth present in the different analysis units is economically attractive to harvest, and to treat this timber as economically accessible. Similarly, for areas supporting immature timber, the PRTSM uses yield tables to determine the volume per unit area that can be expected to be present at rotation age and calculates, based on this volume, whether or not such timber will be profitable to harvest if the price remains unchanged in real terms. If it appears that the timber will be profitable to harvest, then the land area is included in the calculation of the AAC for the analysis unit. In other words, the PRTSM performs its own "net-down" based on a specified delivered roundwood price. By varying the price in fixed increments over a plausible range of prices for roundwood, a stepped supply function for the region is traced out.

Simulating Future Supply, Demand, and Harvesting

The need for a series of annual supply functions from now to as far ahead as one cares to look (e.g., 2050) is only half of the information needed to project roundwood consumption and price trends. The other half is a matching series of demand functions for the same period.

In conducting Forestry Canada's national timber supply study, the plan has been to use the output of the North American timber assessment market model (NA-TAMM), developed by the Forest Economics and Policy Analysis (FEPA) Research Unit at the University of British Columbia (Phelps 1990), to obtain the derived demand functions for delivered roundwood. The NA-TAMM is adapted from the United States version of TAMM.

Figure 8 conceptualizes how the two models (PRTSM and NA-TAMM) are expected to interact to produce supply demand equilibrium points over time.

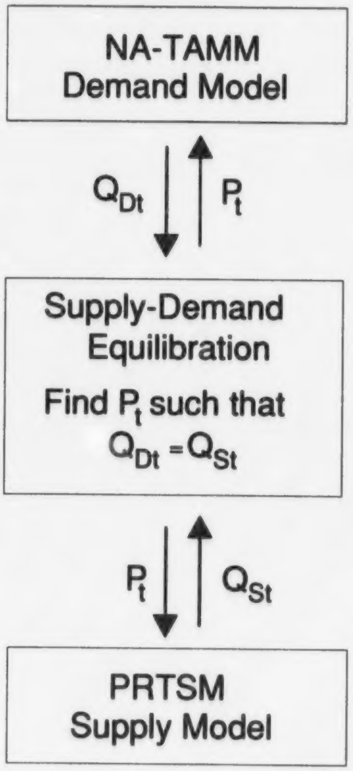

Figure 8. Linking PRTSM to NA-TAMM.

The NA-TAMM provides derived demand functions for roundwood for six Canadian supply regions: the British Columbia coast, the British Columbia interior, the Prairies, Ontario, Quebec, and the Atlantic region. Clearly, the modelling required to produce derived demand functions for roundwood is highly complex. The NA-TAMM employs final forest product demand equations for six demand regions in the United States (northwest, southwest, Rocky Mountains, north central, northeast, and south) and five Canadian demand regions (British Columbia, the Prairies, Ontario, Quebec, and the Atlantic region).

The demand for softwood in the NA-TAMM is differentiated from that for hardwood, and the interaction between the demand for fibre-based products and solid-wood-based products is incorporated into the model.

Are We Facing Imminent Limits to Growth?

A common perception abounds that the rate of increase in roundwood consumption has everything to do with physical availability and little to do with its cost of delivery. This perception leads one to the view that an imminent limit to the availability of roundwood is approaching that poses a dire threat to further growth of the forest sector in Canada.

There is no denying that we live in a finite world, nor is there any doubt that there are ultimate limits to the quantities of timber that the country can expect to grow and harvest on a sustainable basis, but it is a lack of physical availability per se that will limit the rate of increase in timber harvest in Canada for the foreseeable future.

Nonetheless, there appears to be a prevalent view that because annual harvest levels are now approaching specified AAC levels, the potential for future industrial growth is all but over. This is as unrealistic as saying that because the agriculture sector is harvesting annually what it grows, its opportunities for further expansion are over.

Table 1 shows how the volume of industrial roundwood harvested has risen and presents this as an annual percentage increase for each decade over the past 40 years, and how the volume harvested might be forecast to increase over the next 20 years. Can Canada's forests match this demand?

Table 1. Annual percentage increase in Canadian roundwood consumption

Year	Volume Harvested	% Increase for Decade
1950	85 615	-
1960	93 256	0.9
1970	121 419	2.7
1980	155 380	2.5
1990 (estimated)	195 000	2.3
2010 (projected)	260 000	1.4

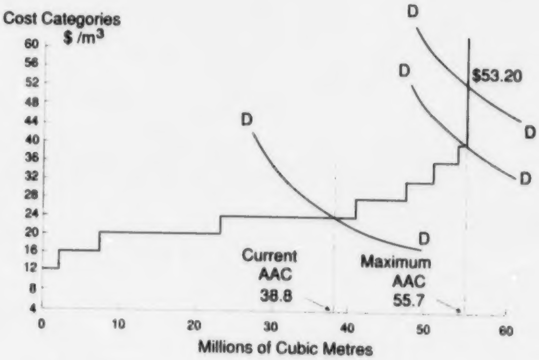

Figure 9. Annual allowable cut for the British Columbia Interior.

Issues such as this can be explored using the PRTSM approach to supply demand analysis. Using the British Columbia Interior again as an example, Figure 9 shows a PRTSM plot of the region's supply function for regulated lands. A demand function has also been sketched in to intersect the supply function at 38.8 million m^3, which is the AAC currently set for the British Columbia Interior. This demand function was not obtained from the NA-TAMM, nor are its shape or slope necessarily accurate. What is of note, however, is that if demand continues to increase, the curve of demand will shift upward to the right, as shown, until it intersects the end of the supply function. As this occurs, the AAC will expand to 55.67 million m^3.

Obviously, if it appears attractive at all to invest in augmenting wood supplies beyond this point, it will appear most attractive financially to expand the AAC of the analysis units with the lowest delivered wood costs (i.e., to lengthen the lowest, flat segments of the supply function).

If one assumes that the rate of harvest will increase at 1.4% per year, as suggested by Woodbridge, Reed and Associates (1989), then, having regard for Figure 9, delivered wood costs can be expected to rise to $40 per cubic metre and the AAC to expand to 55.67 m^3 in about 25 years time. If the AAC is to be increased by investing in silviculture, then it is the price that can be expected to prevail at harvest age, 80 years hence, that is relevant; entrepreneurship must deal with the uncertainty associated with future price expectations.

Clearly, the attractiveness of the investment will be enhanced if expectations are that the real price of delivered roundwood will increase as time progresses, and it is the changing supply demand relationship that will lead to this result if it occurs. For instance, at a real rate of price increase of 1% per year, the price of roundwood can be expected to advance from its current $24 per cubic metre to $53.20 per cubic metre in 80 years time.

To gain a perspective on whether or not it appears attractive to expand the AAC in the $16 per cubic metre delivered wood cost category, given the assumptions made, the net present value required for investment is as follows:

Conversion return:	$53.20 - $16.00 = $37.20 per cubic metre
Planting costs:	$500 per hectare
Annual costs:	$1.50 per hectare
Rotation age:	80 years
Mean annual increment:	5m3•ha-1•year-1
Rate of interest:	4% real
Net present value:	$-\$500 + \frac{[(\$37.20)\ (5)(80) - \$500]}{(1.04)^{80}}$
	$114.71 per hectare

The calculation shows that the net present value is positive, indicating a bare land value of $115 per hectare. Indeed, calculations (not shown) indicate that the net present value is positive for any conversion return exceeding $31 per cubic metre, which means that investment appears attractive in the current delivered wood cost categories of $12, $16, and $20 per cubic metre. The analysis does not guarantee that a different course of action would not result in a higher net present value being indicated.[1]

If it is felt that $500 per hectare is too low as a planting cost, and $1.50 per hectare is too low as an annual cost, then other costs may be substituted. For instance, if it is felt that planting costs need to be shown as $1000 per hectare, then for the net present value to be positive, the mean annual increment will need to be $7.5\text{m}^3 \bullet \text{ha}^{-1} \bullet \text{year}^{-1}$, or, alternatively, the conversion return will need to be $60 per cubic metre.

In any case, the message is clear, crop production costs do matter from the perspective of investment attractiveness, and priority needs to be given to reducing them to as low a level as possible.

Looking again at the supply picture, one can see in Figure 10 that if demand succeeds in pushing the delivered wood price high enough, it will become financially attractive to invest in expanding the sustainable harvest in all of the delivered wood cost categories, not just the lowest cost categories.

It needs to be pointed out, however, that investment in AAC expansion can be expected to have the effect of lowering the future prices of roundwood (supply having been increased over what it otherwise would have been) and that this result must be realistically taken into consideration when deciding how much to invest in augmenting the future supply of timber.

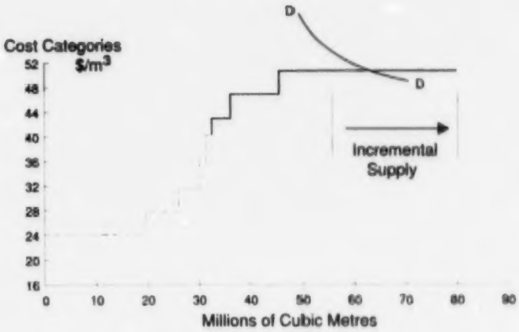

Figure 10. Investment in low cost supply.

It is being assumed here that minimum stumpage will be set by the landowner to earn a return equal to the cost of capital on the investment made in growing the timber crop. Considering the total delivered wood cost equation shown below, an investment in crop production will increase minimum stumpage; conversely, harvesting, site development, and harvesting costs will fall as piece size, stand uniformity, and volume per hectare increase. The likely overall effect of silvicultural investments on delivered wood costs is problematic but highly important.

$$\text{Delivered wood cost} = \text{Minimum stumpage} + \text{Harvest cost} + \text{Site development cost} + \text{Hauling cost}$$

Two major "shocks" with the potential to change the supply and demand picture for roundwood are looming. The recycling of paper is sure to weaken the long-run demand for roundwood; the higher the velocity of recycling, the greater the weakening effect can be expected to be. Conversely, the rising opportunity costs of land use, poised against the use of timber for traditional forest products (largely the result of a growing environmental movement that favours non-timber values), threaten to reduce the land base and old growth available for industrial timber crop production. The potential influence of these shocks is indicated diagrammatically in Figure 11.

The Need for Better Information

Leaving aside questions about future demand for forest products and the potential loss of forestland to other uses, there are many shortcomings in the information base pertaining to forest growth and yield. These must be improved upon if a more informed picture is to be presented of investment opportunities in Canadian forestry.

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[1] The rules of capital budgeting require that two criteria be satisfied: that the net present value of the investment calculated be positive and that where there are two or more mutually exclusive candidate choices, the one promising the largest contribution to net present value be chosen. In the case at hand, there are more than a few alternatives to investing in plantation forestry, including relying on natural regeneration, choosing from a wide array of integrated land use combinations, and choosing a single land use entirely divorced from commercial timber production. Determination of the respective merits of each poses a substantial evaluation task.

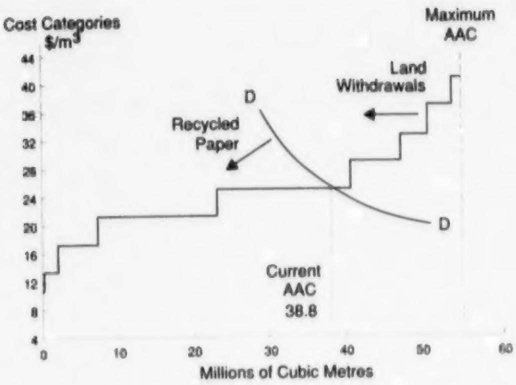

Figure 11. Pressures on timber supply and demand.

Supply can potentially be augmented in a number of ways, namely

- increasing protection to reduce nonharvest drain
- planting to eliminate regeneration delay following stand depletion
- introducing silviculture measures to produce rapidly growing superior stands of preferred species
- improving access
- improving utilization

One of the major weaknesses in the data base, in terms of limiting the amount of economic analysis that can be carried out, is the indiscriminate aggregation of data. It is not useful, for example, to collect information on depletion caused by insects and disease without differentiating between depletion that takes place in growing stock and depletion recorded as the ultimate cause of death in overmature stands. Normalizing the age distribution of the forest, and harvesting the stands at a younger age, can be expected to eliminate the latter type of loss, but not the former. The costs of augmenting supply in the two situations are quite different.

If we are to decide rationally where to best allocate resources, we need to be able to assess at what cost timber supply can be augmented by lessening or eliminating natural depletion caused by pests. With respect to fire damage, simply recording the area burned is not of much use without recording other details. Was the stand killed? How much volume was destroyed? Where did it occur - in the commercially operative area or outside this area? How much of it, if any, was subsequently salvaged? How was the age distribution changed?

The big question, as before, is at what cost can timber supply expect to be augmented by lessening or eliminating fire depletion, and how does the cost per unit volume rise as more and more fire depletion is eliminated?

With respect to undertaking planting to eliminate regeneration delays, the data base on how quickly our forest sites regenerate naturally is poor, to say the least. Similarly, there is a veritable dearth of information available for most species regarding what changes in growth can be expected to result from the application of different silvicultural treatments and forest practices.

The cost of augmenting timber supplies, therefore, in dollars per unit volume is very difficult to calculate accurately. As a result, the trade-offs between investing large amounts for protection versus silviculture are almost impossible to determine because the physical parameters of what is likely to result in either case are poorly known.

Summary

The evidence is compelling that Canada has the capability to expand its roundwood production on a sustainable development basis should it be economically attractive to do so. That attractiveness, however, will depend partly on the global demand for Canadian forest products and partly on how efficient the country can become at growing and utilizing forest crops.

The fact that the way in which AACs are now being used and set differs from the approach followed in years past introduces the need for certain important caveats:

- Firstly, that the convergence of annual harvest levels with AACs should not be allowed to be misconstrued into meaning that the sector has now reached its limit for growth
- Secondly, that industry should not be deluded into concluding that current AACs represent permanent wood supply caps; hence, that no new additional capacity should be contemplated
- Thirdly, that our trade customers and the public at large, including special interest environmental groups, not be left with the mistaken view that for harvest to exceed some published AAC is sure evidence that Canada is overcutting its forests and violating the principle of sustainable development

If the latter view ever takes hold, there will be no changing it.

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What is British Columbia's Timber Supply Forecast to the Year 2050?

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Abstract

The future timber supply of British Columbia is discussed. Although annual allowable cuts (AACs) are calculated for each of the 67 management units (timber supply areas) every 5 years, there is still considerable uncertainty in the process. The nature of the timber inventory and age class distribution is such that there will be a "falldown effect" or reduction in the allowable cut in coastal management units, whereas interior units may show increased harvest rates. The degree to which future harvests will increase or decrease is a function of the response of forests to silviculture, restrictions on the design of harvesting, the market value of wood and its impact on the marginal supply of timber, and the future development of public values. To minimize the uncertainty currently facing the forest sector, it is recommended that a land use strategy be developed for British Columbia that clearly identifies the land available for timber management. Also, it is recommended that AACs be reviewed in any management unit forecasting a falldown of greater than 25%, that more intensive forest management be practiced, that better decision-support tools be developed for both forest management and public information, and that planning cover the entire harvest rotation to ensure that highgrading does not occur.

Résumé

L'auteur examine la réserve future de bois de la Colombie-Britannique. Bien que les possibilités réalisables annuelles soient calculées pour chacune des 67 unités d'aménagement (régions d'approvisionnement en bois) tous les cinq ans, le processus laisse toujours planer de nombreux doutes. La nature des réserves sur pied et de la répartition des classes d'âge est telle qu'on assistera à un «effet d'effondrement» ou à une réduction de la possibilité réalisable dans les unités de gestion côtières, tandis que les unités de l'intérieur pourront connaître une augmentation des rythmes de récolte. La mesure dans laquelle la récolte future augmentera ou diminuera est fonction de la réaction des forêts aux traitements sylvicoles, des restrictions imposées aux plans de récolte, de la valeur commerciale du bois et de son impact sur l'approvisionnement marginal en bois ainsi que de l'évolution future des valeurs du public. Afin de minimiser les incertitudes auxquelles fait actuellement face le secteur forestier, il est recommandé d'élaborer une stratégie d'utilisation des terres de la Colombie-Britannique qui identifie clairement les terrains se prêtant à un aménagement forestier. Il est également recommandé que la possibilité réalisable annuelle soit revue dans toutes les unités d'aménagement prévoyant une diminution de plus de 25 % et que des méthodes d'aménagement forestier plus intensives soient mises en pratique. Il faudrait aussi que des outils à l'appui de la prise de meilleures décisions soient mis au point, tant pour l'aménagement forestier que pour l'information du public, et que la planification porte sur l'ensemble de la rotation pour s'assurer qu'aucune coupe d'écrémage n'est pratiquée.

Introduction

It is very difficult to predict future timber supplies because they are influenced by many factors that are continually changing. Projections can be made based on current knowledge, conditions, and practices, but they are not forecasts of the future. This important distinction should be borne in mind when interpreting any of the projections used in this paper to develop recommendations.

Although it is difficult to predict supplies, projecting current practices forward provides some insight about the future and provides information to characterize the future timber supply. In this paper, an attempt will be made to illustrate British Columbia's timber supply by using examples from two management units. In addition, several of the factors that affect timber supplies will be discussed and a description of how these factors might influence the future will be presented. Lastly, several actions that are required will be identified.

Timber Supply Analysis in British Columbia

British Columbia is divided into 67 management units that are managed as sustained yield timber supply units. Timber supply areas (TSAs) are Crown managed units with multiple volume-based tenures. Tree farm licences (TFLs) are single area-based tenures that are primarily industry managed units. For each management unit, an annual allowable cut (AAC) is reviewed and established by the Chief Forester every 5 years and is mandated by Sections 7 and 28(g) of the Forest Act. The legislation requires that the Chief Forester consider the rate of timber production that may be sustained taking into consideration the following: the composition of the forest and its growth rate; the time required to achieve regeneration after denudation; silvicultural treatments; the standard of timber utilization; and constraints on the amount of timber produced resulting from other resource uses.

In determining the AAC, the Chief Forester uses information generated from timber supply analyses, which project forest inventories over time to assess the timber supply implications of alternative scenarios. Various forest estate models are applied, including an optimization model that is used in TSAs. This optimization model maximizes the volume harvested over the long term subject to several constraints, such as harvest levels, species harvest profiles, minimum harvestable ages, and silvicultural budgets.

Timber supplies are projected and AACs established for each management unit. Each unit is different and is managed individually. By examining timber supplies nationally or provincially, local and regional issues may be masked. Each management unit must be examined individually to truly determine British Columbia's timber supply picture. No attempt will be made here to show projections for all 67 units; instead, two examples have been selected, a coastal TSA and an interior TSA. These examples represent the extremes and will be used to highlight the timber supply issues in British Columbia. In examining these units, an attempt will also be made to describe the common threads that apply to all units.

The most significant differences occur between the coast and the interior. Figure 1 displays a harvest projection of current practices from a coastal and an interior TSA.

The initial harvest level is the current AAC and the final harvest level is the long run sustained yield (LRSY), which represents the maximum volume harvestable over time. It should be emphasized that these are projections of current practices, and if current practices change, the projection and the LRSY will change. Both are dynamic.

The most obvious conclusion one gains from examining these projections is that the timber supply situation is not consistent across the province. The current rate of harvest for the coastal TSA is greater than the LRSY and there will be a "falldown" in timber supplies. In contrast, the LRSY for the interior TSA is greater than the current AAC. This raises several questions: Are the AACs too high on the coast and too low in the interior? Can the falldown be alleviated by intensive management, by technology, or by improvements in utilization? What will happen if the remaining old growth is preserved? Are we overcutting in British Columbia?

To better understand the information provided in these projections, the factors affecting the timber supply projections must be examined in more detail. The key factors affecting timber supplies are the timber inventory available; the productive capability of the land to grow timber; harvest and management practices; economics; and other resource and public values.

Timber Inventory

Given the two principles of maximizing volume and sustained yield, the ideal age class structure would be one of equal area in each age class up to the age at which the average annual growth rate is maximized. To achieve this ideal, the current age class structure will be modified from its predominantly overmature structure to a more equal or "normal" structure. This is clearly illustrated by the dramatic change in the structure of the coastal TSA (Figure 2).

A key factor in managing this transition is ensuring that there is a sufficient area of immature stands growing to replace the harvesting of mature stands. If the mature stands are harvested too quickly, gaps are created

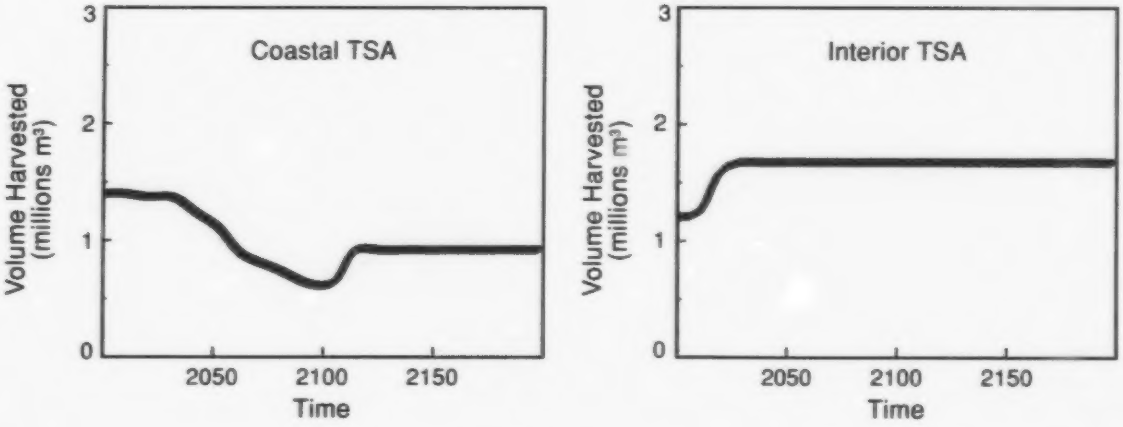

Figure 1. Harvest projections.

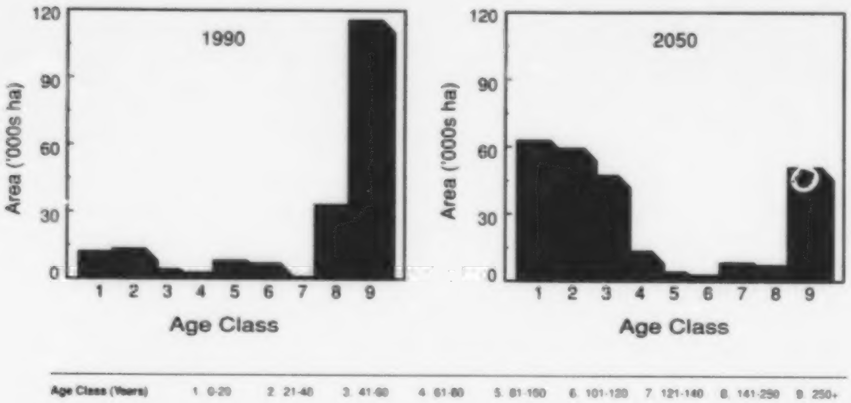

Figure 2. Current and projected age class structure: coastal TSA.

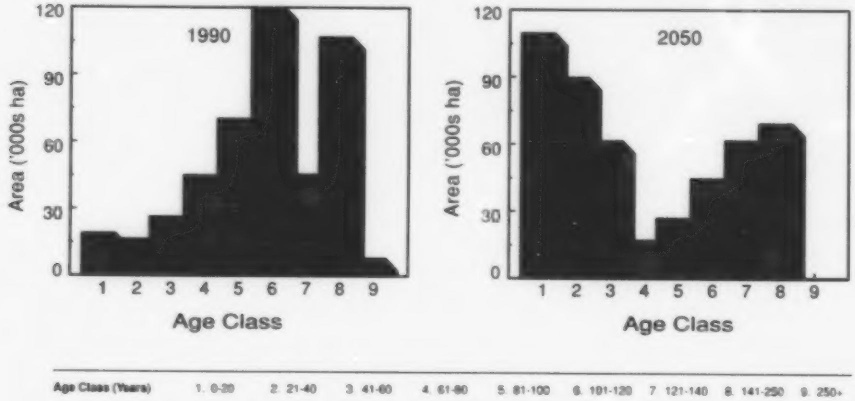

Figure 3. Current and projected age class structure: interior TSA.

in the age class, which results in gaps in the harvest. A gap is projected in this coastal TSA starting in approximately 60 years.

The interior TSA has a significantly different age class structure as illustrated in Figure 3. The current structure is more balanced with more area in the younger age classes. The reason for this difference is that the stands in the interior are primarily of fire origin as opposed to the climax forests of the coast. The transition to a normal forest will be easier and less dramatic in the interior.

Given the projected transition in age class structure, the average age of stands harvested in the future will be younger. Correspondingly, and depending on how much younger the stands are and on species composition, the average volume per hectare will be lower. This change will not be as great in the interior as it will be on the coast because the difference in age and volume of an old growth to second growth stand is not as great. Figures 4 and 5 illustrate these points.

The changing age class structure clearly illustrates the change from old-growth harvesting to second-growth harvesting. It exerts a major influence on the timing and the magnitude of the change and limits many of the options for managing this change. The age class cannot be changed quickly as it can only be altered through changing harvest rates and schedules. As more and more of the mature and overmature age classes are harvested, the flexibility in managing the age class structure and future timber supply decreases. Existing mature stands must be harvested at a rate that provides a smooth transition from old growth to second growth, ensuring that there is always a sufficient inventory of harvestable stands to avoid sharp declines in available supplies.

Productivity

Another important factor affecting timber supplies is productivity. Productivity is the inherent ability of a site to grow wood and it is usually measured as the maximum mean annual increment (MAI). The maximum MAI of the current operable inventory is approximately 2.5 $m^3 \bullet ha^{-1} \bullet year^{-1}$. This measure of productivity relies on the site index of natural unmanaged stands. There-

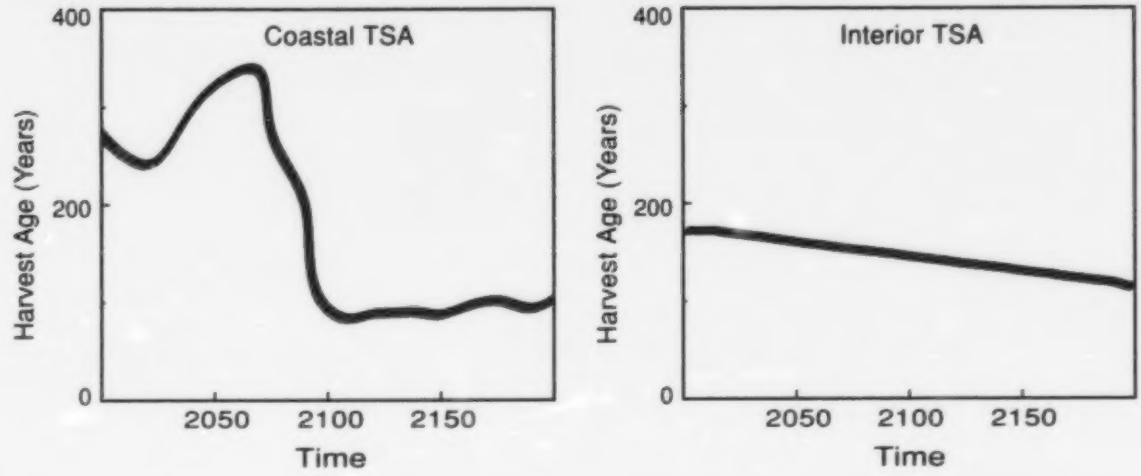

Figure 4. Projected average age harvested.

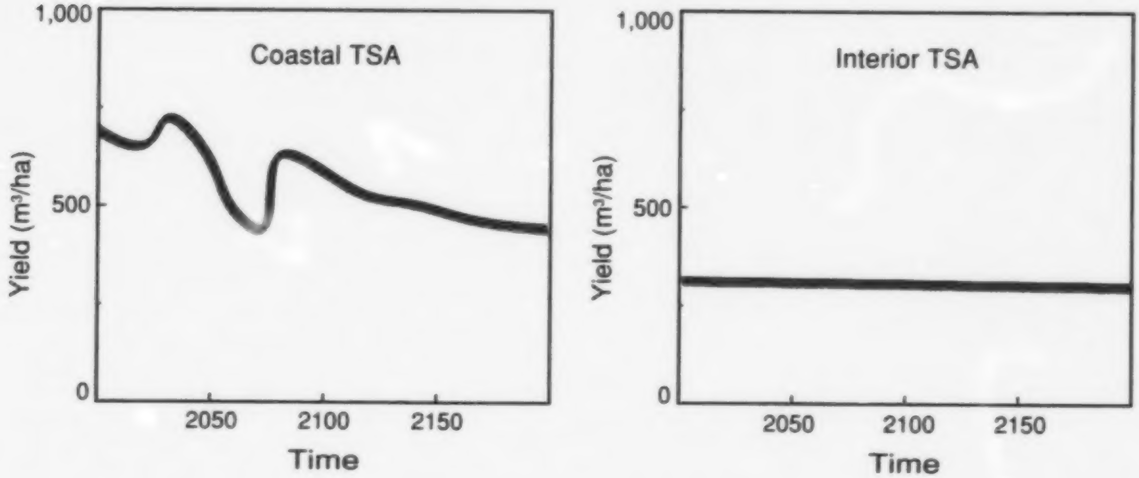

Figure 5. Projected stand volume harvested.

fore, it does not truly reflect the land's inherent productivity, but is simply a reflection of its current capacity to grow the existing crop.

Opportunities exist for taking advantage of a site's inherent productivity, thereby increasing future timber supplies. The most significant opportunity comes from basic silviculture, i.e., matching the best species to a particular site, ensuring that the new stand is established quickly, is free of competition, and is well spaced. It is estimated that gains in stand volume may range from 15-25%.

A good example of the importance of obtaining a well-spaced stand is lodgepole pine. Lodgepole pine has a unique physiology. When overstocked, height growth ceases and the stand stagnates. As site productivity is measured using height, significant areas of unmerchantable stagnated lodgepole pine stands may have been underclassified. If replaced with well-spaced stands, merchantable volumes may increase by 200-300%. Additional productivity increases may be realized from intensive silviculture; however, it is generally thought that the most significant benefit is that of increased value.

Opportunities for increasing forest productivity, have been mentioned, but one must also consider the impact of harvesting and road building. These activities may contribute to site degradation, which in turn impacts negatively on productivity.

The subject of productivity and possible gains is one of significant debate and difference of opinion. It is an area that must be better understood and communicated. It is disturbing that we have experts in our profession that believe that volume gains from intensive silviculture can result in doubling the AAC, whereas others believe that the increases will only be approximately 5%.

Harvest Practices

A third factor, harvest practices, will have the most significant influence on current and future timber supplies. Most areas in British Columbia have significant nontimber resource values that constrain harvest patterns and schedules. These constraints are usually expressed as the maximum percentage of individual drainages that must have mature forest cover at any point, and the size, shape, and distribution of cut blocks. These constraints greatly reduce operational flexibility as harvests must be planned over many years, with several entries or passes into an area. If not carefully planned, the best timber is removed during the first pass, leaving low quality and uneconomic fringes of timber for the second pass, or mature stands required to fill in an age class gap are temporarily reserved in leave strips and buffer zones while adjacent harvested patches "green up." In both cases, these stands may be considered to contribute to the projected harvest forecast, but the operational scheduling, spatial distribution, and complex interaction with resource constraints have not been adequately modeled with our current tools.

As long as supplies are abundant, failing to model these constraints will have little impact on timber supply levels as there will still be sufficient flexibility to incorporate the impacts of deferral on actual operations. However, other resource constraints are growing and the availability of mature stands is shrinking while second-growth stands are not yet harvestable. Scheduling and harvest patterns will play an increasingly important role in determining available timber supplies. They are probably the single most important factor affecting the AAC in the short and midterm.

Current initiatives to redesign the timber supply analysis system are, in part, directed at including spatial resolution such that the complex interactions of harvest scheduling, resource values, and timber supplies can be modeled.

Of course, another important harvest practice that affects timber supplies is the harvest level. There must be a balance between current harvest, the inventory available, and the growth rate. Because our forests are, for the most part, past their optimal growth rate, a harvest level that is too low will actually decrease future timber supplies. Conversely, a harvest rate that is too high will result in gaps in the age class and supplies of harvestable timber in the future.

The higher the AAC is above the LRSY, the faster the forest is transformed into a second-growth forest and the less flexibility there is in harvest planning. A balance between growth and harvest must be achieved to maximize benefits.

Economics

If it is difficult to project growth and the physical supply, it is even harder to project the economic supply. Furthermore, it has an enormous impact on timber supplies. What is the economically operable timber supply? A key step in projecting timber supplies is to first determine the available and operable timber land base. The productive forestland base in British Columbia is 45 million ha, of which only approximately 23 million ha are currently operable.

The supply in British Columbia is very sensitive to market changes, both up and down. There is supply, but is it economical? Will it ever be?

In the Robson Valley TSA, the delivered wood cost was assigned to the forest inventory and three scenarios were examined to determine the supply available under different market prices. The results were dramatic as illustrated in Figure 6.

The economically operable supply more than doubled under different market conditions. What will the supply be in 2050? The answer to this question is unknown, but it is known that supply is extremely sensitive to changes in market conditions. With substantial increases in price, there will be substantial increases in supply. Can we count on this supply? Will the extensive margin expand? What about the other resource values; will the currently inoperable areas be reserved for wildlife habitat?

Public Values

Changing public values and life-styles have not been something that foresters have usually considered. We are taught biology, not sociology. However, we must now also become social scientists.

Public values have changed, and changed dramatically in the last few years. Citizens are telling resource managers and politicians that they are concerned for the quality of life on our planet and that they are willing to tolerate a decrease in affluence if they can be assured that the environment will not be destroyed.

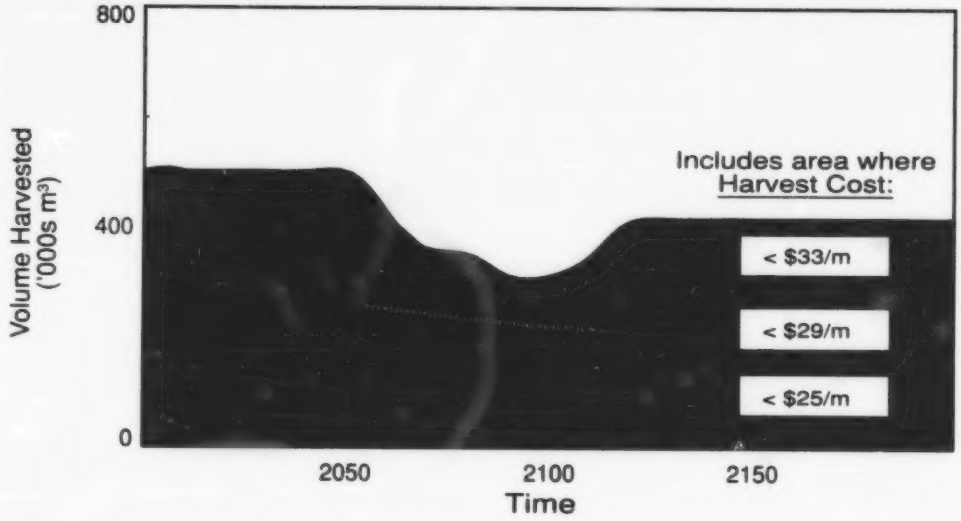

Figure 6. Harvest projection for three operability scenarios.

This is reflected in many ways, including the increasing concern about clear-cutting. British Columbia is being compared to the Amazon and clear-cutting is viewed as destructive, destroying the land and contributing to the greenhouse effect. A bumper sticker promoting the banning of clear-cutting is being sold in British Columbia and is an example of the campaign being waged.

Another way the public is expressing concern is through well-funded and well-planned lobby campaigns to preserve more old growth. Carmanah Valley is a good example. The demand for wilderness and old growth preservation is high. An old growth committee has been struck to develop an old growth strategy. Will more old growth be preserved? How can it not be?

Demographics are changing in several significant ways. There is a strong shift from a rural to an urban life-style. This has significant impact on local land use decisions, such as the Carmanah Valley. The baby boomers are getting older. What influence will they have 20 or 30 years from now when they are senior citizens? What will they demand and how will they influence future timber supplies?

Population growth in Canada is 1.3% annually. We are not sustaining our population and must, therefore, rely on immigration to maintain our work force and standard of living. What values will immigrants have? How will immigration change public values and future timber supplies?

I don't have answers to these questions, but I do know that although these questions have not been asked in the past, and you may consider them far out, they will have to be addressed in the future. Our business has changed.

What Is Needed?

An attempt has been made in this paper to characterize the timber supply in British Columbia and to identify several key challenges. Resource managers can meet these challenges by

1. Developing a comprehensive land use strategy for British Columbia that clearly identifies the land available for timber management. Current land use decisions are ad hoc and are driven by strong lobby campaigns. The land base available for timber management is a moving target.
2. Reviewing the AAC in management units where the falldown is greater than 25% and occurs within 30 years, avoiding age class gaps, and maintaining future options and flexibility.
3. Managing our timber land base more intensively to realize the maximum productivity possible and, at the same time, minimizing soil degradation.
4. Ensuring that the maximum value from our forests is achieved. If the resource is becoming scarcer, a higher value must be realized to maintain the same standard of living.
5. Planning the entire harvest of an area over time to ensure that the area is not high-graded during the first pass and that the supply over time is maximized. Operational plans must also be linked

with strategic plans to ensure AACs are feasible on the ground.

6. Developing improved decision-support tools that incorporate the increased complexity and interaction of other resource values, spatial resolution, economics, and growth projections.
7. Responding to changing public values. Our role as resource stewards is to provide factual information and options to the public. It is the public, however, that decides. We must do a better job of providing the public with information so that they can make informed decisions. We must also include them. Most importantly, we must listen to them.

Summary

What will British Columbia's timber supply forecast be in the year 2050? The answer is unknown. The only thing that can be predicted with certainty is that timber supplies will change significantly. British Columbia is in a period of transition from old- to second-growth management coupled with a major shift in values from resource exploitation to resource conservation. Both factors have increased complexity and reduced flexibility in timber supply management and they work together to exert downward pressure on timber supplies.

Will the AAC come down? Yes, it will have to fall in several management units, but it may rise in others. The downward pressures may be offset by more intensive management and improved utilization. How it stacks up provincially depends on how well and how quickly the profession and the industry respond to change. The transition period will be difficult. Resource managers must communicate and involve the public. We must be flexible, responsive, and adaptive.

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Timber Supply from a First Nations Perspective: "Maybe Squirrel he Climb that Tree..."

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Kluskus Indian Band,
Quesnel, British Columbia

Abstract

This paper attempts to look at timber supply and forest management from a native Indian perspective, drawing upon the experience of the Southern Carrier people of central British Columbia. The paper explains why their land is their culture and why basic, everyday development decisions made by professional foresters can have drastic social consequences for native people, including violent deaths and suicides. It is illustrated that industrial clear-cutting displaces native people and most other nontimber forest users from the land. As an alternative, "wholistic forest use" is proposed and local community forest resource boards are suggested. The need for direct local control over local land use in combination with a system of sustainable forestry is presented. Above all, a call is made for a total forest resource inventory rather than a single timber resource inventory.

Résumé

Le présent article tente d'examiner l'approvisionnement en bois et l'aménagement forestier du point de vue des autochtones, en s'appuyant sur l'expérience des autochtones de la réserve de Carrier Lake sud, au centre de la Colombie-Britannique. Il explique pourquoi leurs terres sont synonymes de culture et pourquoi les décisions quotidiennes de base en matière de mise en valeur prises par les forestiers professionnels peuvent avoir des conséquences sociales énormes pour les peuples autochtones, vu des problèmes comme des morts violentes ou des suicides. Il montre que les coupes rases industrielles forcent les autochtones et la plupart des utilisateurs des ressources autres que forestières à quitter la terre et propose une «utilisation forestière globaliste» et la création de comités communautaires locaux sur les ressources forestières. Il expose les raisons pour lesquelles il est nécessaire d'avoir un contrôle local direct sur les utilisations locales des terres conjugué à un régime de foresterie durable. Il demande, par dessus tout, que l'inventaire forestier porte sur l'ensemble des ressources et non pas uniquement sur les ressources en bois.

Introduction

I am not a professional forester, nor do I pretend to be the ultimate authority on forests and forest use from a native Indian perspective. However, I have been Chief of the Kluskus people for almost 20 years, and the central issue during that time has been forestry and how conventional industrial forestry affects us as native people.

The Kluskus people are a small Southern Carrier Indian Band located west of Quesnel and south of Vanderhoof, British Columbia. The traditional Kluskus territory spreads east of the Coast Range and north of the Chilcotin Plateau. More precisely, our ancestral land comprises the Upper Blackwater River watershed, which is a broad basin of rolling hills at 1200 m elevation stretching 110 km long by about 80 km across.

In this dry, cold, subboreal spruce zone, old growth stands of lodgepole pine, white spruce, and Engelmann spruce predominate, interspersed with large sedge meadows and wetlands supporting beaver, moose, and black bear populations. In the surrounding mountains, especially above the timberline, there are large numbers of moose, mule deer, mountain goat, mountain caribou, California bighorn sheep, grizzly bear, black bear, wolves, and cougar.

The Kluskus people have lived there since beyond memory, archaeologists say for thousands of years. In 1793, my ancestors guided the first "tourist" through the area - Sir Alexander Mackenzie - when he beached his canoe on the Fraser River near Quesnel and asked them how to get to the Pacific Ocean. Shortly thereafter, the Hudson Bay Company and other fur traders moved into the area and our people became involved in the commercial fur business.

Since the turn of the 20th century, small numbers of nonnative people began to move into the area to ranch and to try their hand at trapping and guide-outfitting. More recently, some fishing lodge developers have moved in as well. In some instances, they have intermarried with my people. For the most part, this movement of outsiders into our territory was quite gradual and acceptable to us. We helped them and they helped us. Together we developed a local economy.

1970s: Sudden Change

In the early 1970s, a rumour raced around the Upper Blackwater country that a major road was being constructed westward from Quesnel into the Nazko and Kluskus territory - right into our "backyards." At that time, there were no roads into our area, just packhorse and wagon trails. Construction of a road, therefore, meant a drastic change for us. This was not good news. None of us wanted a road. Our life-styles, livelihoods, and identities were tied to our roadless wilderness environment.

Our land is our culture. To change one is to change the other.

At that time, we had absolutely no idea what the logging might involve, how big the clear-cuts would be, what the impact on wildlife might be, and so on. In fact, we were more concerned about the road, about what the road might bring in upon us and what it might take us out to.

In other words, we worried about the negative social costs of the road, and about such sudden cultural contact and social change. We worried about hunters coming onto our lands and hunting off the moose and deer we depend upon. We worried about the easy access to drugs and alcohol. Above all was the uncertainty of the situation, the feeling of almost total helplessness in the face of a large, distant, and apparently uncaring government determined to bulldoze over us.

Everyone is capable of adjusting to some degree of change, but change that is too sudden, too great, or over which you have no apparent control or understanding can be devastating. That's how the 1970s logging development was for us.

Little did we know then just how the large-scale clear-cutting would destroy our trap lines and our moose habitat. Nor were we ready for the way it demoralized us. Suddenly, our two villages experienced a rash of violent deaths and suicides.

One might ask, Why the suicides and violent deaths? After all, I seem to be implying that basic development decisions by professional foresters resulted directly in suicides and violent deaths. Unfortunately, that is exactly what I am saying. Prior to the road coming in, we never experienced such social problems. Let me try to explain.

When a few large clear-cuts eliminate key winter habitat or summer calving areas for the moose and deer we depend upon, or when another group of large clear-cuts (each 300-1000 acres (121-405 ha) in size) destroys the best trapping areas of that same person's trap line, what has inadvertently been done is that a person's livelihood has been taken away. That person's only way to earn a living has been taken away.

That trapper is probably a middle-aged man who has prided himself in supporting a large family by hunting, trapping, guiding, and helping local ranchers put up hay and maintain fences. Suddenly, and I emphasize suddenly, he is out of business. Suddenly he feels helpless, a useless man in his own eyes. He can no longer support his family. He can no longer hold his head high as a good hunter and trapper. In the 1970s, he could probably speak very little English, let alone read and write it. Today, in the 1990s, chances are he has had 4-8 years of schooling and some contact with industrial society. In either case, the impacts are the same: sudden, total, and absolute change. He has lost his livelihood and cannot foresee any alternatives.

In most cases like this, the man applies for welfare - at the office in Quesnel, 320 km away. He now has to buy his family's food because his larder - the hunting and trapping grounds belonging to his family - has been stripped bare. Often, he takes the $180 he is entitled to and uses it to purchase alcohol. Sometimes his wife, in equal despair, joins him. This kind of drinking often leads to violent death.

Within his family, his children are also affected. They too feel the despair and often end up using drugs and alcohol. Youths are the ones who tend to commit suicide. In Nazko, a village of 150 people, six of the most educated young people died within about 1 year of the road going through.

This is the social impact and social cost that foresters' seemingly innocent, day-to-day decisions can inflict upon my people. That is why we asked the provincial Minister of Forests in the 1970s for a moratorium and direct input into land-use planning. That is why we are still asking the same things today - only much more emphatically. This time we won't take "no" for an answer.

What's Wrong with Forestry in British Columbia?

One would think that as we moved from the 1970s to the 1990s that these social costs would decrease, that my people would be better able to adjust, and that forest planning would have improved? Unfortunately, this has not been the case.

The Kluskus people today do have a better understanding of Canadian society and the system of government. Since the 1970s, however, forestry has changed dramatically, and politicians are just as elusive today as they were then. What's more, foresters don't consult or involve natives in planning and decision-making processes any more now than in the past.

Consider the increased annual cut today, and the increased speed at which the cutting is accomplished. Consider also the corresponding reduction in the number of logging and milling jobs available, especially to native people, as a result of changes in technology (from chain saws to feller-bunchers) and as a result of the elimination of many small logging and milling operators who were forced out of the industry by changing forest policies and corporate buy-outs. Above all, consider the increased size of clear-cuts today.

There is no way we could have anticipated such changes in the industry. Nor could we have predicted their impacts on our people.

These changes have resulted in dramatic reductions in wildlife populations (especially moose, deer, and many furbearers). Impacts on trap-lines are especially direct and serious. Let me illustrate using one family's trap line just north of Kluskus village.

A few years ago, Westar Timber Company was given timber harvesting rights in this area. Even though the Chantyman family had officially registered their trap line with the British Columbia government in the 1930s, with the understanding that this would guarantee them their trapping rights within the area, the same government turned around in the 1970s and gave to Westar, a newcomer, preemptive timber harvesting rights over the same land and forests.

More than 90% of the old growth spruce stands were logged out during the first pass. By the end of the second pass, almost all of the mature pine will be gone as well. The small, stunted growth (pulpwood) in between the sawlog stands has also been cut. In short, the trap line has been destroyed. This case is used only as an example. I am not trying to single out Westar nor the Chantyman family. What has occurred here occurs elsewhere.

What is left for the trapper or for the guide-outfitter who also has registered rights to an area? Where will the animals live? What about the fact that the resources being taken are "aboriginal rights"? What good are rights without the resource?

During the 18 years since the loggers first pushed their way into the Blackwater country, I have been the Chief of my people. I have had to find ways to deal with the government, with the forest industry, and, of course, with professional foresters. It has been quite an experience, quite an education, but a painful one for me and for my people.

What have I learned? I have learned that the overall system of government and land-use decision-making in British Columbia doesn't work. You may feel from your perspective that it does, but from my people's perspective it does not. Someone, surely, gets some benefits, but we are left with the costs. Hence, our funds and our people's energies go toward fighting the logging.

The system of government seems to be there primarily for the large, multinational corporations. The legislation was written for them, the regulations are designed for them, and the Forest Service appears to work primarily for them. Why, for example, do the largest companies pay the lowest stumpage, whereas the small, selective loggers pay the highest stumpage? Selective harvesting is like "value-added logging." It leaves the forest almost better than it was. Yet the selective logger is penalized for his efforts.

Similarly, the rights of trappers, guide-outfitters, water rights holders, and wilderness tourism operators are ignored and overridden by industrial logging in British Columbia. What's more, Indian bands aren't even recognized as stakeholders in British Columbia. Nor are we recognized as legal entities. I guess we don't exist! Sadly, I've learned that to be recognized and to get the attention we deserve, we are forced to resort to road blockades and whatever other form of direct action it takes to stop the system in its tracks.

Apparently, the system in British Columbia is incapable of dealing equally and justly with all resource users. It ignores those of us who already live in and make our living from the forests. It ignores our rights and our resources. It is biased almost totally in favour of industrial logging - the latecomers in the forest business.

We nontimber forest users need our resources in standing trees; as integral, healthy forests - producing not just wood fibre, but all the other products and resource values that forests provide. Conversely, the sawmills need their trees lying down on the back of a logging truck heading for the mill. Thus, we have a fundamental conflict between seemingly mutually exclusive forest uses. If one party gains, the other party loses.

Does it have to be this way? The only reason this has become such a win/lose situation is because of the expanding size of the annual cut and the nature of clear-cut harvesting today. This could be changed to a win/win situation by reducing the annual allowable cut, introducing partial cutting in place of clear-cutting, and legislating direct community involvement in the land use planning process.

The only benefit derived from conventional clear-cut logging is the quick, short-term profits amassed by the contract logger and the mills. Everyone else loses, even the government, which hopes to earn quick revenue through the stumpage. Consider the fact that in 1988-1989 (a good year in the forest industry), the British Columbia government netted an average revenue of only $0.02 per cubic metre of wood harvested! That same year, the United States National Forests netted between $10 and $16 (Can.) for the same volume of wood, with 25% taken off the top for the counties where the logging took place. In the Cariboo Forest Region of British Columbia, we lost $2.80 per cubic metre in 1988-1989! (The calculations are done by registered professional foresters from United States and British Columbia government agencies.)

The public also loses because the highly mechanized logging and milling systems used employ fewer people. Although this can be looked upon as greater output per worker, it also means fewer jobs per volume of wood harvested. Furthermore, it encourages foresters to take out more trees rather than to make more product from fewer trees.

British Columbia's production sawmills are over-designed. They are tooled to produce an almost endless number of two-by-fours and nothing else. In return, a minimum number of jobs are created, and a minimum dollar return is received through stumpage and taxes.

From a native Indian point of view, let me stress some other concerns. Clear-cutting displaces other forest-based jobs, such as wilderness tourism, guiding, trapping, ranching, mushroom picking, and small-scale logging. Following large-scale clear-cutting, the forest is useless for other applications. In addition, the clear-cut forest is not replaced with another forest, it is replaced with a sterile plantation that can't support the plants and animals my people need to survive. As mentioned earlier, most of the people displaced from the forest end up on welfare, supported by the taxpayers, not by the forest companies.

Judging from my conversations with other Chiefs and with other people involved in rural British Columbia economies, this debate about abusive forest practices is just beginning. Foresters can expect to be swamped with criticism in the future; they can expect to have to justify (or disclaim) soil erosion and soil nutrient deficiency problems, water supply and water quality problems, the extent of not sufficiently regenerated lands across British Columbia, the disappearance of old growth forest ecosystems, and so on. They can also expect more roadblocks!

The forestry profession is going to have to learn to sit down with the general public, in particular with representatives of Indian Bands, to make land-use decisions, to refine and clarify forest policy, and to develop integrated forest use plans together.

What Alternatives do We Propose?

After nearly 20 years of struggling to protect ourselves from encroaching logging roads and expanding clear-cuts, the Kluskus Band Council decided a few years ago to stop simply reacting to the plans and initiatives of others, and to start initiating some plans of our own. We opted for a proactive stance in the face of industrial encroachment.

Together with our neighbours, the Ulkatcho Band at Anahim Lake, we decided to push for an area-based forest tenure for ourselves. We chose to apply through the Minister of Forests for a tree farm license (TFL). Our intention was to manage the TFL for all resource values on the land, not just for timber.

TFLs are a recognized provincial forest tenure under the British Columbia Forest Act. Conventionally, TFLs have been granted primarily to corporations and used almost exclusively for timber production. (The one British Columbia exception is the municipality of Mission's small community-based TFL, which is also managed for recreation, watershed, firewood, etc.)

Yet, there have long been other forest uses in British Columbia. Small communities of people living within the forest have utilized the ecosystems in a variety of ways. They have jointly used the forest in an ecologically and economically sustainable way for more than a hundred years in British Columbia, even longer in the case of my people. In recent years, however, the government of British Columbia has permitted the large forest corporations to disregard the rights of local people, just as they have done to the Kluskus people.

Thus, our TFL proposal was designed to ensure the survival of nontimber forest uses forever. To emphasize that we would be managing our TFL in a different manner than that followed by the forest companies, that we would be managing all of the forest resource values rather than just for the one that brings the quickest cash return (timber), we used the term "wholistic tree farm license" to describe these licenses.

This means that we view and treat the forest as a "whole," managing for the survival of the ecosystems and the nearby forest-dependent communities, of which we are a part. Timber is just one of many equal resource values within the forest and the forest economy.

One of our elders used to say, "Indian when he log, take one tree here and one tree there. Maybe squirrel want to climb up this one here. Maybe lynx want to use that one over there." In other words, we believe in selective logging. We cannot condone the large-scale clear-cutting that many foresters seem to think is good forestry and sound economics. It is stealing from your (and our) children. Today's short-term gain is their long-term pain.

How Does "Wholistic Forest Use" Work?

Briefly, wholistic forest use means wise use and protection of forests throughout the full spectrum of human uses of forests. In the words of the forestry consultant who designed this model for us, "Forests are diverse, interconnected webs which focus on sustaining the whole (i.e., all life forms), not on the production of any one part alone" (Hammond et al. 1989). We must focus on the protection of ecosystems rather than on the production of forest commodities.

All parts of a forest are essential. We started by ethnographically demarcating our traditional tribal territory. Then we mapped each family's traditional use areas in detail. Then we hired a forestry consultant to assist in designing and developing the TFL and in submitting the formal application to the government.

Parallel to this, we also established a local, community forest resource board, made up of representatives from all sectors of the local economy and community - a rancher, a trapper, a small logger, a local businessman, a guide-outfitter, an Indian band member, and so on - and chosen by their peers. In conjunction with their own technical staff and with the band's TFL management staff, this board will zone the entire region in question and establish policies and standards. Where possible, all board decisions are to be made by consensus.

Between ourselves and the Ulkatcho Band, $250,000 worth of studies towards this end have already been completed. Our six-volume report and associated mapping corroborates the necessity and feasibility of moving to such sustainable forestry and away from the conventional approach. Our neighbours studied the report and are now lobbying for its adoption by the British Columbia government.

For instance, the nonnative neighbours of the Ulkatcho Band at Anahim Lake have not only lobbied Victoria for the adoption of the band's wholistic tree farm license (W-TFL) proposal but they have also formed the "West Chilcotin Forest Resource Board" and have begun taking matters into their own hands. With the assistance of three foresters, they have refined the W-TFL land-use zoning, tentatively approved those zones in which "wholistic timber management" will be permitted, and recalculated the annual allowable cut (AAC) to a volume equal to half of the Ministry of Forest's previous estimate. Their target is sustainable forestry.

People in the Blackwater country are currently organizing themselves towards establishing a similar local resource board. They are also looking at land-use zoning, harvesting criteria, and a sustainable AAC. Contract negotiations with local mills are also under way.

Wholistic Forest Use Zoning

The wholistic forest use zoning system divides the total land base into forest use zones to facilitate land-use planning for the area, to ensure that all land uses protect the forest, and to ensure that each land use does not damage other uses. In all, there are about 80 land use zones within our TFL area.

The objective of zoning is to integrate the various forest uses. A primary land use was determined for each zone, i.e., its highest and best use. This was done in consultation with local residents, who know the land best. The primary users have top priority at all times, although constraints and limitations are placed on them to protect other users (human, animal, and plant) of each zone and to preserve the ecology of the zone during and after human use.

Five different zone types were identified: culture, ecologically sensitive, fish and wildlife, recreation-tourism-wilderness, and wholistic timber use. All of the zonal uses are compatible. Each use blends to some degree with the others. For example, a zone whose designated primary land use was "culture" (important to local heritage or current local use) could also include secondary uses, such as fish and wildlife, tourism, etc. The most difficult primary forest use to blend with others, of course, is "wholistic timber use." Yet, by considering the full range of harvesting alternatives, from selective horse logging to contour strip/patch logging (<10 ha in size), it is even possible to integrate some of the other uses into the timber management zones as well.

The decision-making path for determining wholistic forest use zones follows a simple procedure of moving from the most sensitive to the least sensitive areas or zones across the landscape. This process is depicted in Figure 1. This flowchart demonstrates how selection for the protection of cultural use areas is accomplished first, followed by ecologically sensitive areas, fish and wildlife habitat areas, recreation-tourism-wilderness areas, and, finally, wholistic timber use areas. More than half of the overall landscape ends up being classified as being appropriate for "wholistic timber use."

In one important watershed, next to the Ulkatcho Band's village, a detailed land-use study carried out by the Chief and his technical staff resulted in some very important findings. To compare present nontimber uses of the Beef Trail Creek watershed with proposed clear-cutting plans of the Ministry of Forests, the Chief met with the three trappers, two guide-outfitters, one rancher, many mushroom pickers, and numerous hunters who use the area. After interviewing these people, the technical staff produced overlay maps and annual harvest figures.

Based on this analysis, it was determined that a dollar equivalent of approximately $225,000 (Can.) is harvested each year from this one drainage area by Ulkatcho Band members alone. It should be noted that this estimate does not include additional nonnative hunting returns, potential wilderness tourism values, or the potential selective logging that could be carried out concurrently with all the other forest uses, thereby nearly doubling the $225,000 revenue.

Using a 100 year rotation age (rather than the 200 or 300 years that reflect the actual age of the trees), this

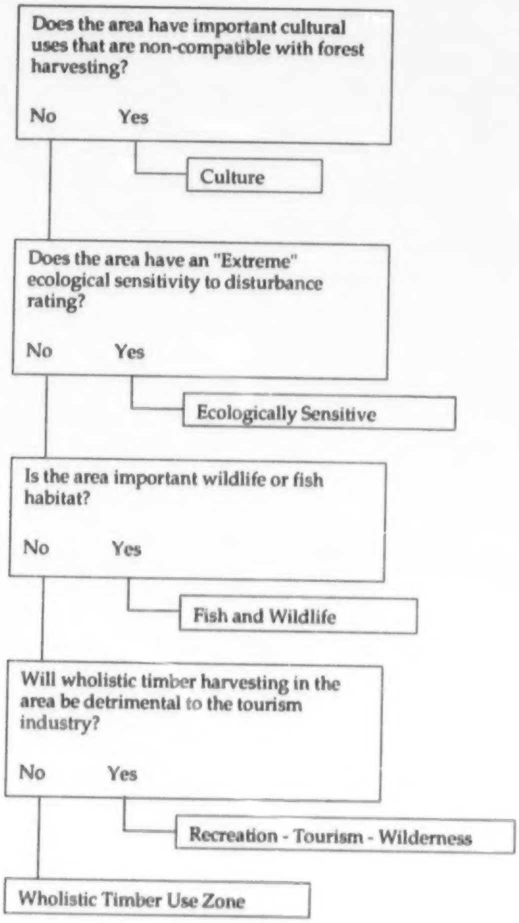
Does the area have important cultural uses that are non-compatible with forest harvesting?
No
Yes
Culture
Does the area have an "Extreme" ecological sensitivity to disturbance rating?
No
Yes
Ecologically Sensitive
Is the area important wildlife or fish habitat?
No
Yes
Fish and Wildlife
Will wholistic timber harvesting in the area be detrimental to the tourism industry?
No
Yes
Recreation - Tourism - Wilderness
Wholistic Timber Use Zone

Figure 1. Decision-making path for wholistic forest use zone typing.

means that in nontimber values this watershed would generate a minimum of $25 million between now and the year 2090. If the site were clear-cut, according to the company, it would generate $10 million in sawlogs plus about $25 million in two-by-fours, for a total of about $35 million - once - during that 100 year rotation period. But that's not all.

Remember, if the area is clear-cut, those people who gain benefits from that land at present will be displaced and will have to seek alternative sources of income, which for some people will almost certainly be welfare, drawn annually for many years to come. Hence, these additional cumulative costs should be deducted from the gross benefits anticipated from the clear-cut logging.

On the other hand, if the same watershed were carefully zoned (which it has been) and selectively logged according to a multiresource management plan designed to maintain a predominantly old-growth forest profile (similar to what is there now), the net benefits to the local community and to the larger economy would be substantially greater than in either of the above cases. By managing for old growth we can guarantee a continual source of pine mushrooms, to cite one example. If we clear-cut and/or if we harvest on a short rotation, we cannot. The same applies for all of the other forest values within that one watershed.

By managing the forests "wholistically," with direct local planning input through a community forest board, we believe that everyone can "win." The forest industry and the government will be assured of a long-term supply of good quality sawlogs (and chips), while local forest user/residents, particularly native people, will be assured that their livelihoods and other forest values will be protected.

Conclusions

The key is meaningful local control over land use in combination with a system of sustainable forest management and sensitive timber harvesting. Within British Columbia, where land title treaties were never signed between the tribes and the government, long-term, area-based forest tenure (such as a TFL) placed in the hands of the local tribe or band would accomplish the forest management objectives discussed above and help resolve aboriginal title and rights difficulties still outstanding between the government and native people.

In the Cariboo-Chilcotin region of British Columbia, these concepts and this general approach to forestland management appeals to more than just the nontimber forest users living in the bush. Even International Woodworkers of America leaders and members, for example, are promoting it. There is general public consensus today that we are rapidly overcutting our forests, and that we will soon put ourselves out of business. While the multinational corporations can and do move elsewhere around the globe once the local resource supply is depleted, the local residents, the workers, and especially native Indians, must remain and make do with the mess that is left behind.

Recommendations

To date, forest inventories have been limited to timber only. I hope that the insights from a native Indian perspective, plus our "wholistic forest use" approach, will give you cause to seek out ways to inventory and manage the nation's forest resources from a total resource management standpoint and with the long-term welfare of the people of Canada in mind.

Just as the health and welfare of a "spotted owl," for example, is an indicator of the health of an old growth forest, I believe that the health and welfare of the local user/residents of a forest is an indicator of the health of the larger forest economy.

Because the metropolitan regions of Canada are dependent upon the local resource economies of the hinterland, their future hinges upon the health and welfare of all three - the "spotted owl's," the local forest user/residents (especially Canada's native people), and the overall forest economy.

I ask that forest inventory statistics be studied from the native's perspective too. If the native Indian's livelihood is not at risk and the forest resources they depend upon are secure, I think you can be assured that the long-term welfare of the country's forest economy is secure as well.

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Forecasting Future Wood Supply at Corner Brook Pulp and Paper Ltd.

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Abstract

This paper is a case study of a recently completed wood supply analysis carried out at Corner Brook Pulp and Paper Ltd. It aims to provide some background information about forest conditions in Newfoundland prior to the analysis, and to describe the methods and assumptions used to forecast the wood supply available to Corner Brook Pulp and Paper Ltd. over the next 80 years. Results of the analysis are discussed and comments are made on what is needed to improve the analysis in the future.

Résumé

Le présent article est une étude de cas d'une analyse de la réserve de bois effectuée récemment à la compagnie Corner Brook Pulp and Paper Ltd. Il a pour but de fournir des données de base sur l'état de la forêt à Terre-Neuve avant l'analyse et de décrire les méthodes et les hypothèses utilisées pour prédire les réserves de bois dont pourra disposer la compagnie au cours des 80 prochaines années. L'auteur examine les résultats des analyses et formule certains commentaires sur les améliorations à apporter afin qu'on puisse mettre au point ce type d'analyse à l'avenir.

Introduction

The forestry community in Newfoundland is relatively small. Two paper companies and the Crown control virtually all of the commercial forestland on the island. Although this paper deals with the future wood supply for Corner Brook Pulp and Paper Ltd., the analysis for the entire province was a joint effort by the three groups. Much of the work involved in developing yield curves for the simulation model and updating the inventory was carried out by the Forest Management Division of the Newfoundland Department of Forestry and Agriculture.

Corner Brook Pulp and Paper Ltd. is a wholly owned subsidiary of Kruger Inc. of Montreal. The company operates a newsprint mill at Corner Brook on the west coast of Newfoundland. After a recently completed modernization program, the production capacity of the four paper machines at the mill is approximately 1000 t of newsprint per day. Slightly more than 1 million m^3 of wood per year is required to supply the mill's fibre needs. To meet this demand, the company manages some 2 million ha of timberland throughout western and central Newfoundland. Three quarters of this is Crown land licensed to the company. These licenses expire in the year 2037. The remaining 25% is company freehold land. Approximately 800 000 ha is considered productive forestland. The remainder is a mixture of water, bog, barren, and scrub.

Present Situation

Three major insect epidemics over the past 25 years have shaped the future of forestry in Newfoundland for at least the next rotation. An outbreak of hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), began in 1966 and continued until 1972. An effective chemical control program was carried out in 1968 and 1969, but before the outbreak ended, fir stands containing 12 million m^3 of wood in western and central Newfoundland were killed (Hudak and Raske 1981). As the looper outbreak was collapsing in 1971 and 1972, populations of the eastern spruce budworm, *Choristoneura fumiferana* (Clem.), were increasing. By 1979, tree mortality was occurring in softwood stands on the island containing a total volume of 38 412 000 m^3 of wood (Hudak and Raske 1981). This outbreak finally ended in 1985. In 1983 and 1984, looper populations were increasing in eastern and central Newfoundland and by 1987 this new outbreak had spread into remaining mature and overmature fir stands in the western part of Newfoundland. The outbreak is still active and 55 400 ha of moderate and severe defoliation are forecast for Newfoundland in 1990 (Hudak et al. 1990).

Constant insect epidemics over the past 25 years have drastically altered the wood supply situation for the forest industry in Newfoundland. On Corner Brook Pulp and Paper Ltd.'s timber limits, the merchantable softwood growing stock has decreased from an estimated 51 704 000 m^3 in 1970 to 26 643 000 m^3 in 1990. As well, the age class distribution of the softwood forest has changed from a predominance of overmature forest to approximately equal amounts of immature and overmature stands, with insufficient area in the middle-aged classes to meet future wood supply needs (Figure 1). Obviously, these changes have brought into focus the need to reevaluate the adequacy of Newfoundland's forests to meet the future needs of the industry. A critical analysis of future wood supplies was urgently needed.

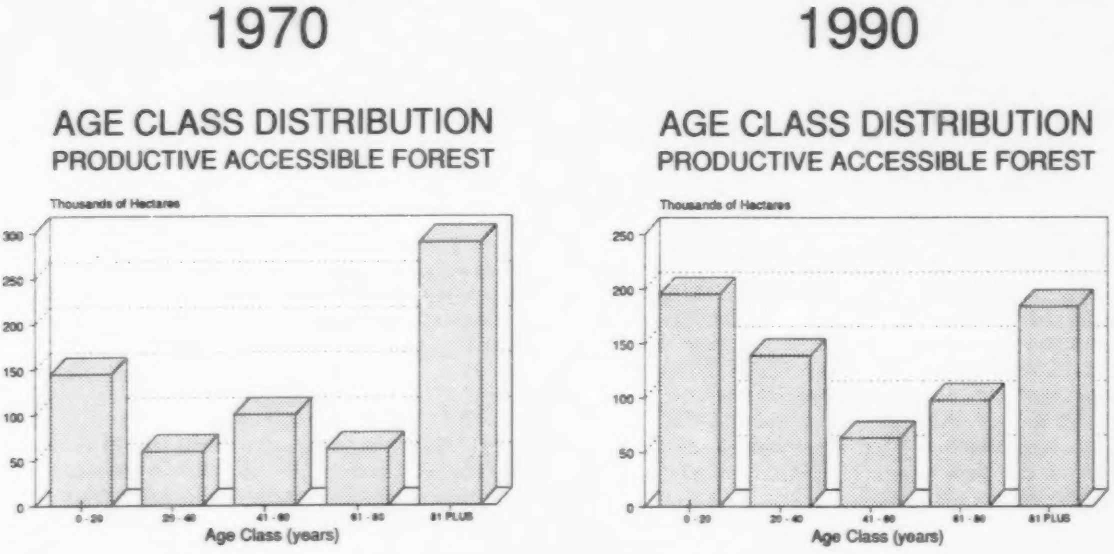

Figure 1. Comparison of age class distribution in 1970 and 1990 for Corner Brook Pulp and Paper Ltd.

Methodology

The first requirement for a realistic analysis of future wood supplies was to ensure that the inventory data base was updated for harvest, wildfire, and insect damage. It was then decided that productive forestland should be classified according to its availability for forest management. Each stand in the inventory was assigned to one of three classes:

1. Land Class I - Land fully available for forest management. Productive forestland where no operational or regulatory restraints could be identified that would limit recovery of all merchantable volume from the stand.
2. Land Class II - Land partially available for forest management. Constraints of a regulatory nature exist that limit the availability of these sites for forestry. Municipal control areas, protected watersheds, and the shores of scheduled salmon rivers are examples of class II lands.
3. Land Class III - Land not available for forest management. Operational or regulatory constraints prevent these sites from being used for forestry. Stands on steep slopes, isolated stands, ecological reserves, wilderness areas, and provincial parks are included in land class III.

With the inventory data base updated and a new evaluation of the land available for forest management, future wood supplies could be forecast. The FORMAN wood supply model was used to forecast future wood supplies. FORMAN is a sequential inventory projection model developed by Eric Wang for the New Brunswick Executive Forest Research Committee, Inc. It was developed as a management tool to aid in evaluating different forest management strategies. It is not a complex statistical model. Rather, it is a bookkeeping device that permits the user to describe the forest resource in dynamic, quantitative terms; to specify harvest and silviculture strategies; and to observe changes in the resource over time in response to these strategies (Wang et al. 1987). FORMAN requires three basic types of information to forecast the future state of the forest: (1) A description of the initial state of the forest. This description takes the form of a list of forest classes. Forest classes are aggregates of forest stands that have common characteristics. These were derived from the updated forest inventory. (2) A management strategy, or rules for ordering the forest classes for harvesting, planting, or spacing and the levels of each of these activities. These are input each time the model is run. (3) A quantitative description of how each forest class changes over time. In other words, yield curves.

No quantitative yield curves were available for Newfoundland's forest, so these had to be developed. This was done by the provincial Department of Forestry and Agriculture with input from Forestry Canada, Newfoundland region and the two paper companies in the province. In all, 91 yield curves based on region, species composition, site class, and crown density class were developed. Figure 2 shows a group of yield curves for balsam fir on average sites in western Newfoundland. These are not highly sophisticated mathematical relationships. They are simple representations of stand development, specifically designed for use in FORMAN, and they give results that field foresters in New-

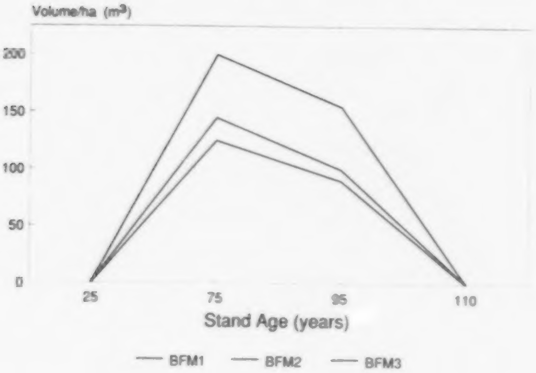

Figure 2. Yield curves for natural balsam fir in western Newfoundland.

foundland feel comfortable with. They are derived from existing temporary and permanent plot information from the forests in Newfoundland.

Results

As with any simulation, assumptions about factors not simulated in the model must be made before using FORMAN. The major assumptions in this simulation were

1. Ninety per cent of land class I and 50% of land class II were available for management
2. A set of regeneration assumptions for each region and species group was agreed upon to assign future yield curves to forest classes cut in the model
3. Inherent in the model is the assumption that all stands are equally accessible and available for harvesting
4. Maximum sustainable yields generated by the model will be reduced by 20% to account for waste and unsalvable losses from fire, insects, cull, etc.

Other assumptions, which define the management strategy being evaluated, are input at the time the model is run. Various combinations of the level and timing of harvests, level of planting and spacing, and rules for harvesting were tested to evaluate several possible futures with respect to long-term wood supplies.

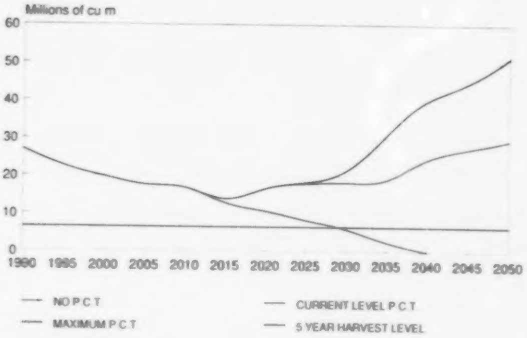

Figure 3. Impact of precommercial thinning on projected growing stock from 1990 to 2050, Corner Brook Pulp and Paper Ltd.

For this case study, three different silviculture regimes and three different harvesting rules were analyzed. All of these simulations assume a constant level of harvest equal to the forecast mill demand. Figure 3 shows the projected growing stock until the year 2050 with no precommercial thinning (PCT), the current level of PCT, and thinning every stand that becomes eligible for PCT. In all cases, priority has been given to harvesting the oldest stands first. Regardless of the level of PCT chosen, the growing stock is going to decrease until about 2015. If no PCT is carried out and harvesting continues at a rate sufficient to meet mill requirements, the growing stock will be depleted to the point where the forest cannot meet the mill's needs by the year 2030. If the current level of PCT is maintained, there will be sufficient wood supplies to meet future needs and even an increase in the level of growing stock after the year 2035. If every stand that becomes eligible for PCT is thinned, the future will see an increase in the level of growing stock sooner, but not before about 2025. Figure 4 shows the projected growing stock under three different harvesting rules. FORMAN allows the user to choose any combination of six harvesting rules or to input a harvesting sequence file that states the exact sequence of harvesting for each forest class. Corner Brook Pulp and Paper Ltd. is working with a limited amount of overmature forest and very few middle-aged stands that are maturing to provide future wood supplies. Therefore, it is critical that harvesting be scheduled to maximize the utilization of overmature stands even though many of these stands are beyond their peak volume yields. This scenario illustrates the sensitivity of future wood supplies. In all cases, the current level of silvicultural activity has been maintained. If harvesting is

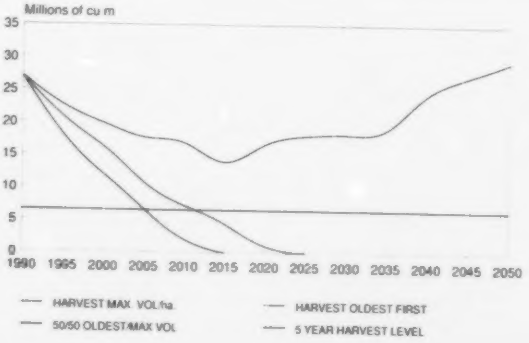

Figure 4. Impact of varying harvest rules on projected growing stock from 1990 to 2050, Corner Brook Pulp and Paper Ltd.

scheduled strictly in order of descending age, sufficient growing stock can be maintained to meet future needs. If harvesting is scheduled to get the maximum volume yield per hectare regardless of age, however, the growing stock would be quickly depleted and would be unable to meet needs by 2005. If these two rules are mixed and 50% of the harvest is scheduled using each rule, the growing stock would still become depleted and would be unable to supply the mill by the year 2015. In actual fact, at least 70% of the harvest must be scheduled in the oldest stands to maintain sufficient growing stock to meet future needs.

Forest Management Implications and Future Needs

These simulations clearly show that if harvesting is continued at a rate sufficient to meet the forecast mill demand, growing stocks will decrease for the next 20-40 years regardless of the management strategy followed. It will be possible to sustain a harvest level sufficient to meet the mill's demand only if the current PCT program is continued and if every effort is made to schedule harvesting so that losses to natural mortality in the overmature stands are minimized. There is little or nothing that can be done in terms of silvicultural practices to alter the wood supply situation over the next 20-40 years.

Attempts to improve inputs into the model are continuing, especially the yield curves for managed stands. Wood supply estimates must be updated whenever new data become available. Where possible, this type of simulation must be used to illustrate the impact of decisions on such things as withdrawals of forestland and new environmental regulations on future wood supplies. At some time in the near future, it will be possible to tie the model directly into the geographic information system and get outputs in map form showing where the model is harvesting stands.

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